IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

VOITH PAPER GMBH & CO. KG	:	
	:	Civil Action No. 07-226 (JFF)
Plaintiff,	:	
	:	
v.	:	
	:	
JOHNSONFOILS, INC.	:	
Defendant.	:	

DEFENDANT'S REPLY TO PLAINTIFF'S RESPONSE TO MOTION TO STAY THE PROCEEDINGS PENDING REEXAMINATION OF THE PATENTS-IN-SUIT OR IN THE ALTERNATIVE FOR LEAVE TO FILE A MOTION FOR SUMMARY JUDGMENT PRIOR TO AUGUST 20, 2008 THAT U.S. PATENTS 5,718,805 AND 5,972,168 ARE INVALID

I. INTRODUCTION

In Plaintiff Voith Paper GmbH & Co. KG's ("Voith") response ("Voith's Mem.)(D.I. 33) to Defendant, JohnsonFoils, Inc. ("JohnsonFoils") Motion To Stay The Proceedings Pending Reexamination Of The Patents-In-Suit Or In The Alternative For Leave To File A Motion For Summary Judgment Prior To August 20, 2008 That U.S. Patents 5,718,805 And 5,972,168 Are Invalid (D.I. 28), Voith relies on mischaracterizations and exaggerated claims of prejudice and misconduct to distract the Court from the clear need for either a stay pending reexamination or summary determination.

II. ARGUMENT

A. A Stay Pending Reexamination Is Appropriate in This Case

1. Voith's Reexamination Statistics Are Not Persuasive

Voith attempts to make much of PTO statistics showing that approximately 64% of all reexaminations result in claim changes to support its position that the complexity of the infringement analysis will be increased with more claim limitations. See Voith Mem. at 9, citing, Akzenta Paneele + Profile GmbH v. Unilin Flooring N.C. LLC, 464 F. Supp. 2d 481, 485 n.1 (D. Md. 2006).[1] To the contrary, these statistics support the position that the Court should stay proceedings until it knows what claims will be at issue. Further, Voith fails to explain how such claim cancellations or amendments increase the complexity. If the claim is canceled or amended, that argues for a stay so that only valid claims need be considered.

Voith's argument also ignores the fact that the PTO's own statistics from 2006 show that in almost 74% of all cases, an even greater number, the claims are either canceled or amended. See Voith Mem. Ex. 8. Voith's statistics demonstrate that a stay will prevent the Court from either performing an unnecessary claim construction, where claims are cancelled, or having to repeat a claim construction where claims are changed by the PTO.

1 The importance of claim changes should not be discounted because amended narrower claims could not support a damage claim for past infringements because of intervening rights. Laitram Corp. v. NEC Corp., 163 F.3d 1342, 1346-47 (Fed. Cir. 1998)(Accused infringer not liable for infringement of reexamined patent during period before issuance of reexamination certificate because claims were substantively changed during reexamination.)

2. Different Patentability Standards Have No Bearing In This Case

Voith's reliance on the different patentability standards in the district court and the PTO is a red herring and is of no moment. "The thought that a PTO decision [in a reexamination] may unnecessarily complicate the litigation and could create an awkward situation if different conclusions are reached overlooks that challenging validity in a court and requesting PTO reexamination 'are concepts not in conflict.'" Ethicon, Inc. v. Quigg, 849 F.2d 1422 (Fed. Cir. 1988), quoting In re Etter, 756 F.2d 852 (Fed. Cir. 1985).

Moreover, the different standards relied upon by Voith support JohnsonFoils' position. Before the district court, a patent is presumed valid and the party asserting invalidity must prove the facts to establish invalidity of each claim by clear and convincing evidence. 35 U.S.C. § 282; Kaufman Co. v. Lantech, Inc., 807 F.2d 970, 974 (Fed. Cir. 1986). However, in a reexamination proceeding before the PTO, there is no presumption of validity and the PTO Examiner needs only a preponderance of the evidence to reject the patent claim(s) as unpatentable. Ethicon, 849 F.2d at 1427. Once, the PTO finds the claims invalid, the inquiry in the district court will end as there will be no patents at issue.

3. Voith Exaggerates Any Prejudice To It

Voith's claims prejudice based on statistics that show the average pendency of a reexamination proceeding is over twenty-one (21) months and the possibility

that the Patents-In-Suit will expire shortly.[2] See Voith Mem. at 11-12. Voith does not explain why it slept on its rights without seeking relief earlier when it has known of JohnsonFoils' activities for many years. In reality, there is no prejudice since the filing of this action preserved Voith's right to monetary damages if its patents are found valid and infringed. Woodard v. Sage Prods., Inc., 818 F.2d 841, 853 (Fed Cir. 1987).[3]

Voith attempts to escape the implications of its decision not to seek a preliminary injunction by arguing that decision is not a waiver of its property interest in patent exclusivity. See Voith Mem. at 13.[4] Voith's failure to seek preliminary relief is objective evidence from which to infer that the patentee will not suffer irreparable harm *pendente lite*. See Woodard, 818 F.2d at 854. In Woodard, the Court denied the plaintiff's attempt at an interlocutory appeal from a decision on summary judgment dismissing one of three defendants from a patent infringement case. In so holding, the Court rejected the patentee's argument that

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[2] This argument ignores the fact that the median pendency is only 17.6 months. See Voith Mem. Ex. 8. More importantly, as noted in JohnsonFoils' Opening Brief, reexamination proceedings are conducted with special dispatch. 35 U.S.C. § 305. In addition, Voith has substantial control over the duration of the reexamination process. It will have two months to respond to any PTO's Office Actions unless it seeks extensions of time. See Manual of Patent Examining Procedures (MPEP) § 2662(a)(1), attached as Exhibit 3 to JohnsonFoils' Opening Memorandum.

[3] There is no question as to JohnsonFoils' ability to meet a monetary judgment so that is not at issue in this case.

[4] Although Voith makes much of the delays at the PTO and JohnsonFoils' likely appeals, Voith assumes without any basis that it will prevail and forgets that the appeal process after the district court case would also likely take this case beyond the expiration of the Patents-in-Suit. Moreover, obtaining a permanent injunction is no longer automatic. See eBay Inc. v. MercExchange, L.L.C., 126 S. Ct. 1837, 164 L. Ed. 2d 641 (U.S. 2006). Accordingly, given the facts of this case, it is highly unlikely that Voith will ever obtain an enforceable permanent injunction. Both sides know that and if there is any tactical advantage, Voith has waived any objection by failing to seek a preliminary injunction.

expiration of the patent-in-suit in three years would deny the plaintiff its right to injunctive relief because the plaintiff could still obtain monetary damages and had not sought preliminary injunctive relief. Id.

Voith slept on its rights and cannot now be heard to complain of any prejudice resulting from a stay of these proceedings pending the reexaminations.

4. JohnsonFoils Will Be Prejudiced

Voith asserts that the sole prejudice to JohnsonFoils is the expense involved in litigating the matter. Although JohnsonFoils does not discount the substantial expense of defending a baseless patent infringement matter, the prejudice to JohnsonFoils is greater than mere expense associated with litigation. As set forth in detail in paragraphs 24 - 29 of JohnsonFoils Counterclaim, this litigation has and is likely to continue to disrupt and distract JohnsonFoils from its business. In addition, if this court finds that the Patent-In-Suit are valid and infringed and awards damages, but the PTO later finds the Patents-in-Suit invalid, JohnsonFoils will have a difficult time recovering those damages. See Akzenta, 464 F Supp. 2d at 485 n.1 (D. Md. 2006).

B. This Case Is Ripe For A Summary Determination

JohnsonFoils recognizes this Court's reluctance to entertain early summary determination; however, JohnsonFoils feels strongly that the case for obviousness is so strong that it would be a waste of the parties' and judicial resources to allow the case to continue without considering summary judgment.

In arguing against JohnsonFoils' request for leave to file a motion for summary judgment, Voith admits that the determination of obviousness is a legal determination, but argues there are a number of factual inquiries "including, *inter alia*, the level of ordinary skill, the scope and content of the prior art, and secondary consideration of obviousness that must be considered." See Voith Mem. at 14. This assertion is not only wrong, it is unsupported and contrary to the law that the non-moving party must "do more than simply show that there is some metaphysical doubt as to the material facts." Matsushita Elec. Indus. Co. v. Zenith Radio Corp., 475 U.S. 574, 586-87, 106 S. Ct. 1348, 89 L. Ed. 2d 538 (1986) (internal citation omitted). The non-moving party "must set forth specific facts showing that there is a genuine issue for trial." Fed. R. Civ. P. 56(c). In this action, the Patents-in-Suit admit that the prior art is very close and that the invention is very narrow. The cited Reexamination prior art is from the same field of endeavor and is directly on point. Here, Voith's unsupported arguments are not a basis for denying either a motion for leave to file for summary judgment or grant of the summary judgment.

a. The Level Of Skill In The Art

Voith exaggerates the factual complexity of determining the level of skill in the art. The Federal Circuit recently followed the straightforward method of ascertaining the level of ordinary skill in the art as follows: (a) determine the technical problem that the subject patent solved; (b) determine how the problem was solved; and, (c) identify the person who could arrive at the solution. Dystar Textilfarben GmbH v. C.H. Patrick Co., 464 F.3d 1356, 1362-1363 (Fed. Cir. 2006).

The technical problem here is defined by the Patents-in-Suit.

> With this known web-forming device, fiber webs of relatively good formation can also be formed. With respect to this, however, the demands have increased considerably recently, so that further improvements are desirable.
>
> SUMMARY OF THE INVENTION
>
> The object of the invention is so to develop a twin-wire of the aforementioned kind that the quality of the fiber web produced is further improved, particularly with respect to its formation (cloudiness), and that the twin-wire former can easily be adapted to different operating conditions (for instance, with regard to quantity and drainage behavior of the fiber suspension).

See Exhibit 1 Col. 2. At column 3, lns. 1-17, the '805 Patent admits that the solution to the problem was a combination of known elements.

In Dystar, the Federal Circuit overturned the jury's determination of a low level of ordinary skill in the art by analyzing the claimed invention in comparison to who would understand the claims. Dystar, 464 F 3d. at 1362-1363. The person that would understand the claims was the person who could solve the alleged problem. In this case, that person has familiarity with twin wire former paper making and paper making machines. Id.

The prior art relied upon by JohnsonFoils does not argue for esoteric teachings. Rather, it only argues that "one of ordinary skill in the art is a person having sufficient experience with the paper making process, approximately 2 years, to appreciate both machine functions and paper making." That person could certainly combine known prior art elements to solve the problem identified by Voith, especially when they are admitted known elements.

Finally, the level of ordinary skill in the art is a moot question because it simply establishes the threshold for determining the scope and content of the prior

art.[5] Here, there is no need for such a determination because the art is in the exact same field as the alleged invention.

b. The Scope And Content Of The Prior Art

The Supreme Court recently addressed the issue of determining the scope and content of the prior art, in KSR Int'l Co. v. Teleflex Inc., 127 S. Ct. 1727 (U.S. 2007) which makes it clear that, after determining any problem allegedly solved by the patent, one of ordinary skill in the art can put the pieces of the puzzle together even if the pieces come from different technologies. Id. at 1745-46. In other words, the scope and content of the prior art is expansive by law.

The Verti-Forma references and the title of the Patents-in-Suit disclose the very same technology: Twin Wire Former[s]. Clearly, references that discuss the same technology cannot be outside the scope and content of the prior art under the expansive standard enunciated in KSR.

Voith's attempt to bring in secondary considerations is immaterial to the analysis in this case. The Federal Circuit has held that a strong *prima facie* case of obviousness eliminated the power of secondary considerations to insulate claims from invalidation despite the trial court's explicit finding that patentee provided "substantial evidence of commercial success, praise, and long-felt need." Leapfrog Enters. v. Fisher-Price, Inc., 485 F.3d 1157, 1162 (Fed. Cir. 2007).

[5] Dystar, 464 F. 3d at 1370 ("Although this court customarily discusses a motivation to combine as part of the first Graham factor, the scope and content of the prior art, see SIBIA Neurosciences, Inc. v. Cadus Pharm. Corp., 225 F.3d 1349, 1356, motivation to combine is also inextricably linked to the level of ordinary skill.")

c. **Secondary Considerations At Issue**

The Patents-in-Suit already identify the secondary consideration at issue and the alleged unexpected result is not new. Specifically, the Patents-in-Suit allege improvements to paper making that "satisf[y] even the highest requirements" and result in a final fiber web that has the same properties on both sides (i.e., the paper is not two-sided). See U.S. Patent No. 5,718,805 (the "'805 Patent"), Exhibit 1 at col. 1, lns. 45-62; and col. 2, lns. 42-45; and U.S. Patent No. 5,972,168 (the "'168 Patent"), Exhibit 2 at col. 1, lns. 46-52; and col. 2, lns. 44-47. As noted above, this so-called unexpected result was not new. The Parker paper taught making non-two-sided paper with a twin wire former as early as 1989. Parker states: "An inherent feature of this type of former is the more or less symmetrical drainage of the suspension from both sides. Accordingly, the resulting sheet structure, with regard to the "fines" distribution particularly, is substantially symmetrical and non-two-sided...." See Parker Sheet Forming Process, Exhibit 3 at 86.

Even if the court does not follow the Leapfrog holding to ignore secondary considerations, the allegedly surprising or unexpected result was known years before. There are no secondary considerations of patentability that overcome the *prima facie* case of obviousness.

B. **Voith's Assertions Regarding JohnsonFoils' Citation Of Prior Art Are Baseless**

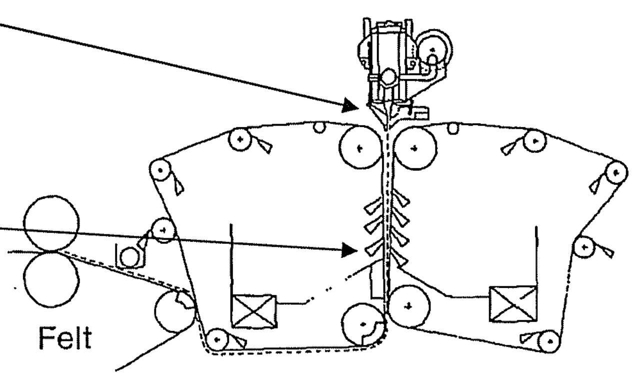
Voith's argument takes the argument for form over substance to the extreme. To support its argument, Voith quotes the Paper Machine Felts and Fabric reference and states that the quoted text is the "totality of the description of Verta-

Forma contained in the Paper Machine article." See Voith Mem. At 17. Voith goes on to argue that the Paper Machine article makes absolutely no reference to "no single wire predrainage," "zig zag drainage strips," "twin wire zone free of rolls," or any division of the paper forming path into region I, II, and III. Voith's arguments completely disregard the illustrations contained in the Paper Machine article which shows these features graphically in a manner that is clear to all who read it. Voith would make the standard one of using the exact words from the patent rather than the law of anticipatory disclosures.

Voith asserts that JohnsonFoils blatantly imposes its characterization of the diagram elements of Figure 3 to the prior art references, and asserts that neither the authors of the cited articles nor one of ordinary skill in the art would have understood the diagrams in the cited prior art "in the context of the specification of the Patents-in-Suit." See Voith Mem. 17. But, even a cursory search for the allegedly missing feature emphasized in Voith's brief versus the figures themselves shows that Voith's arguments are baseless:

"no single wire predrainage"
- Figure shows the slurry is
is dispended directly into
the twinwire zone.

"zig zag drainage strips"
- Figure unequivocally shows
strips

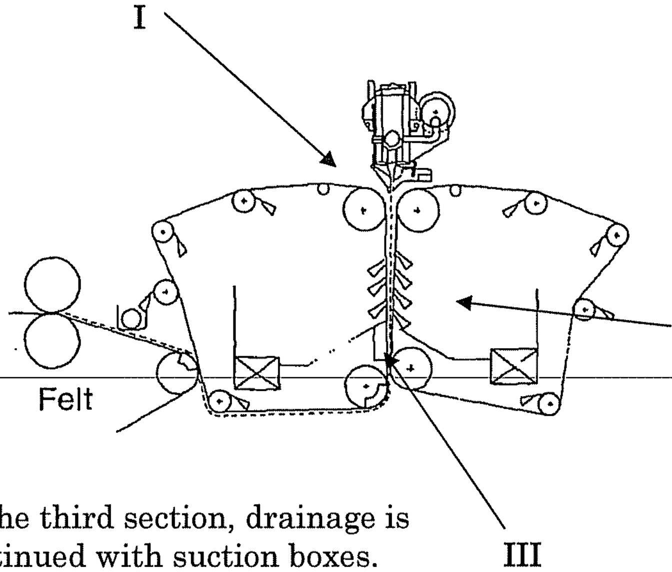


"twin wire zone free of rolls."
- Figure shows no rolls in
the twin wire zone.

The figures taken from each of the Verti-Forma references illustrate "no single wire predrainage," "zig zag drainage strips," and a "twin wire zone free of rolls" virtually as they are illustrated in the Patents-in-Suit. In addition, a comparison of the description of the three sections taken from the patent versus the cited prior art shows that all of the missing elements are there. The invention described and claimed in the '805 Patent concerns a twin wire former used in paper making. See Exhibit 1, col. 1, lns. 14-17. Briefly, the twin wire former drains water from a "fiber suspension" that is the starting material for paper making. Id. at col. 1, lns. 14-43. The suspension is applied between two wire loops or belts. Id. at lns. 32-35. In the relevant portion of the machine, the belts are positioned closely together in an opposed relationship to form a "twin wire zone" that is divided into three sections. Id at lns. 14-43. In the first section, fiber suspension is discharged into the entry of the twin wire zone (See annotation "I" below). Id. In the second section, the suspension is carried past drainage strips. (See annotation "II" below).

Id. And, in the third section, drainage is continued with suction boxes. (See annotation "III" below). Id.

In the first section, fiber suspension is discharged into the entry of the twin wire zone.



In the second section, the suspension is carried past drainage strips.

In the third section, drainage is continued with suction boxes.

While, the sections are labeled according to the Patents-in-Suit, it is not hindsight to point out that a reference disclosed the claimed combination years before the filing date. Instead, it provides *prima facie* evidence of invalidity. Likewise, the division of the paper forming path into region I, II, and III is not hindsight, but simply pointing out what is clearly illustrated. Voith admits that the labels are from its patents. The labels simply track the claimed invention.

One skilled in the art would understand the combination of these elements given the explicit illustration of the very combination alleged to be the invention.

C. JohnsonFoils' Requested Stay Or, In The Alternative, For Leave To File For Summary Judgment Was Entirely Proper

Throughout its brief, Voith makes repeated attempts to characterize JohnsonFoils' request or a stay or alternative request for leave to file a motion for summary judgment as a sanctionable request that is somehow beyond the pale. Voith propounds this argument despite the fact that many courts regularly stay actions pending the outcome of reexamination proceedings. Inland Steel Co. v. LTV Steel Co., 364 F.3d 1318, 1320-22 (Fed. Cir. 2004) (discussing, with approval, a stay pending reexamination in the action); ASCII Corp. v. STD Entm't USA, 844 F. Supp. 1378, 1381 (N.D. Cal. 1994) ("It is clear from the cases cited by both parties that there is a liberal policy in favor of granting motions to stay proceedings pending the outcome of USPTO reexamination....").

Likewise, summary judgment is not only provided for in the rules, but is "properly regarded not as a disfavored procedural shortcut, but rather as an integral part of the Federal Rules as a whole, which are designed 'to secure the just, speedy and inexpensive determination of every action.'" Celotex Corp. v. Catrett, 477 U.S. 317, 327 (quoting Fed. R. Civ. P. 1); Avia Group Int'l, Inc. v. L.A. Gear Cal., Inc., 853 F.2d 1557 (Fed. Cir. 1988)

While JohnsonFoils acknowledges that this Court indicated that it disfavored a stay of litigation and does not grant summary judgment lightly, JohnsonFoils believes it was proper to bring this simple issue before the Court with formal briefing where each party is provided the opportunity to put its arguments before

the Court.[6] Essentially, Voith seeks to convert this Court's preferences into an order forbidding JohnsonFoils from requesting the Court to reconsider its position. Such a position is both contrary to law and is not JohnsonFoils' understanding of this Court's comment that these procedures are not granted routinely.

Voith primarily relies on Nat'l Fire & Marine Ins. Co. v. Robin James Constr., Inc., 478 F. Supp. 2d 660, 663 (D. Del. 2007) for the proposition that sanctions are awarded for violation of scheduling orders. However, the defendant in Nat'l failed to provide initial disclosures in violation of the Rule 16 Order and a later order by the court. These actions are clearly distinguishable from the instant case.

Voith's reliance on L.E.A. Dynatech v. Allina, 49 F.3d 1527 (Fed. Cir. 1995) for the proposition that sanctions are awarded for bad faith motions to stay proceedings is not only misplaced, its assertion is questionable. In Dynatech, the court awarded sanctions to the plaintiff where the defendant had originally opposed a motion to stay pending reexamination and then flip flopped its position and moved for a stay of proceedings on the eve of trial. Clearly, this is distinguishable from the instant case where JohnsonFoils provided early notice to Voith and is moving for a stay in the early stages of litigation prior to any substantive discovery.[7]

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6 Although Voith repeatedly alludes to Rule 11 Voith has not yet perfected any of the procedures for asserting a Rule 11 claim.

7 Voith's argument that JohnsonFoils' withdrawal of the subpoenas and the original motion for summary judgment does not cure its innocent mistake once again takes form over substance to a new height. JohnsonFoils notes that Voith mistakenly failed to file an attorneys eyes only document when it filed its response to the JohnsonFoils' Motion (D.I. 35). Just as JohnsonFoils corrected its errors without court intervention, Voith promptly corrected its error. JohnsonFoils suggests that this is a better approach to litigation rather than the parties moving for sanctions at every procedural misstep.

III. CONCLUSION

As set forth in detail in JohnsonFoils' opening memorandum and this memorandum, there is good cause for either staying this action pending the reexaminations at the PTO or granting JohnsonFoils leave to move for summary judgment.

Dated: September 24, 2007

Respectfully submitted,

Seitz, Van Ogtrop & Green, P.A.

/s/ Patricia P. McGonigle

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CERTIFICATE OF SERVICE

I, *Patricia P. McGonigle*, Esquire, hereby certify that on this 24th day of September 2007, I electronically filed the foregoing pleading with the Clerk of Court using CM/ECF which will send notification of such filing to all counsel of record.

/s/ *Patricia P. McGonigle*

Patricia P. McGonigle (ID No. 3126)
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EXHIBIT 1

US005718805A

United States Patent [19]

Egelhof et al.

[11] Patent Number: 5,718,805

[45] Date of Patent: *Feb. 17, 1998

[54] **TWIN WIRE FORMER**

[75] Inventors: **Dieter Egelhof**; **Klaus Henseler**, both of Heidenheim, Germany; **Werner Kade**, Neenah, Wis.; **Albrecht Meinecke**, Heidenheim, Germany; **Wilhelm Wanke**, Heidenheim, Germany; **Hans-Jurgen Wulz**, Heidenheim, Germany; **Rudolf Bück**, deceased, late of Heidenheim, Germany, by Else Bück, legal representative

[73] Assignee: **J. M. Voith GmbH**, Heidenheim, Germany

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,500,091.

[21] Appl. No.: **556,769**

[22] Filed: **Nov. 2, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 286,948, Aug. 8, 1994, Pat. No. 5,500,091, which is a continuation of Ser. No. 55,918, Apr. 29, 1993, Pat. No. 5,389,206, which is a continuation of Ser. No. 773,965, filed as PCT/EP90/01313, Sep. 8, 1990, abandoned.

[30] **Foreign Application Priority Data**

Aug. 22, 1989 [DE] Germany 39 27 597.3

[51] **Int. Cl.**^{6} **D21F 1/00**

[52] **U.S. Cl.** **162/301**; 162/300

[58] **Field of Search** 162/203, 300, 162/301, 303, 348, 352

[56] **References Cited**

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5,500,091	3/1996	Buck et al.	162/301

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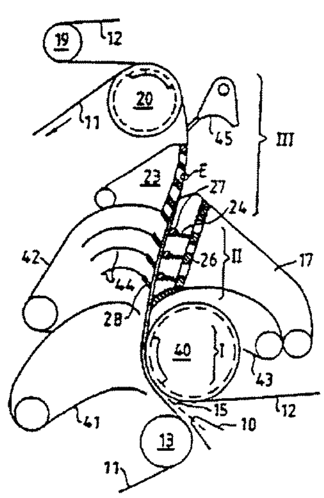
Primary Examiner—Karen M. Hastings
Attorney, Agent, or Firm—Ostrolenk, Faber, Gerb & Soffen, LLP

[57] **ABSTRACT**

In a twin-wire former for the production of a paper web, two wire belts (**11** and **12**) together form a twin-wire zone which is divided into three sections (I, II and III). In the first section (I) the two wires (**11**, **12**) travel over a curved forming shoe (**16**), or a forming roll (**40**). They form there a wedge-shaped inlet slot (**15**) with which a headbox (**10**) is directly associated. In the second section (II), several resiliently supported strips (**27**) rest against the lower wire (**11**) and between each of said strips (**27**) a rigidly mounted strip (**28**) rests against the upper wire (**12**). In the third section (III) both wire belts (**11**, **12**) pass over another curved forming shoe (**23**).

5 Claims, 2 Drawing Sheets



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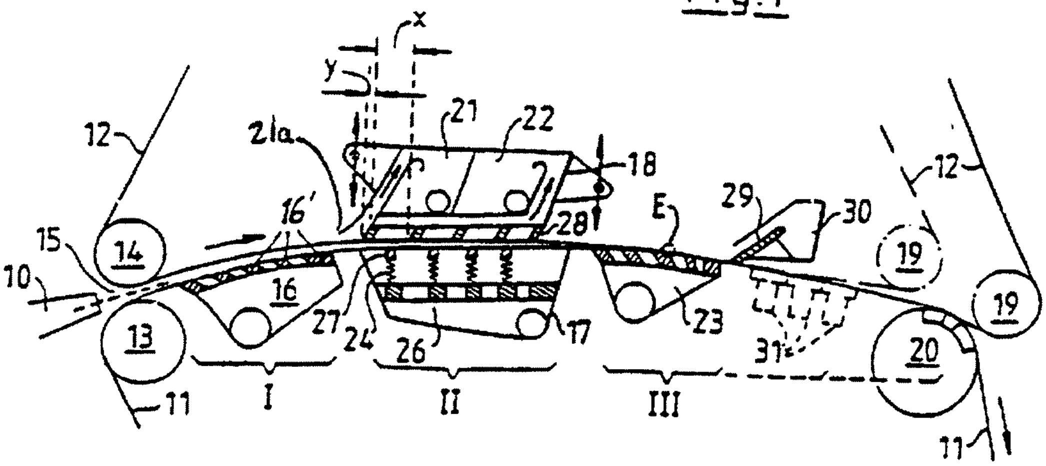

Fig.2

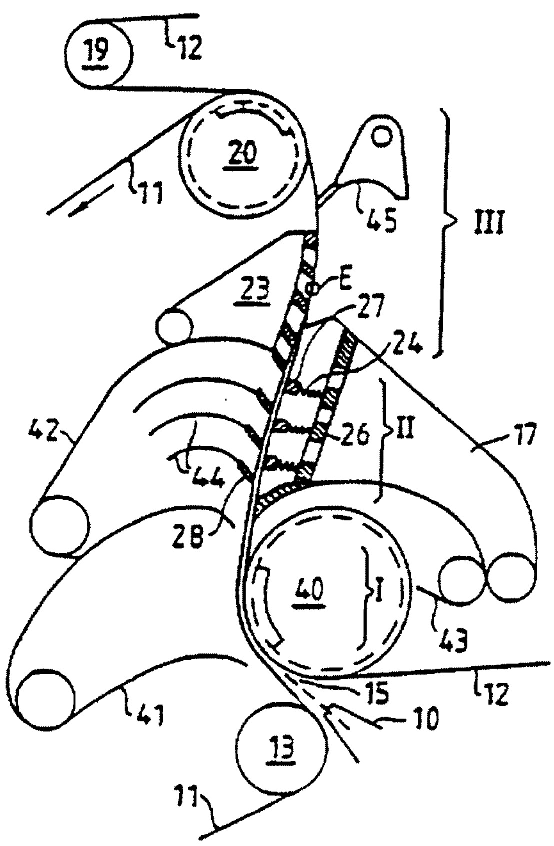

Fig.3

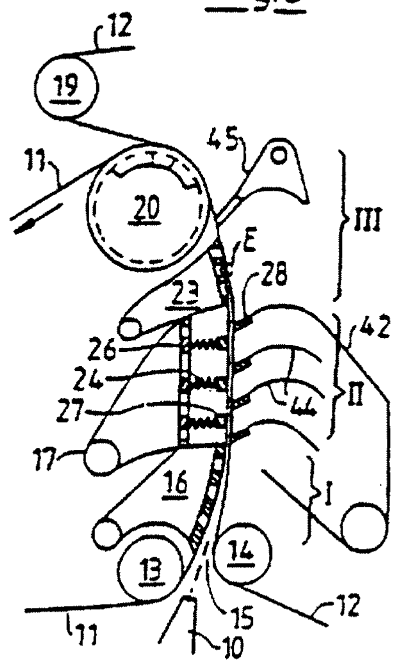

Fig.4

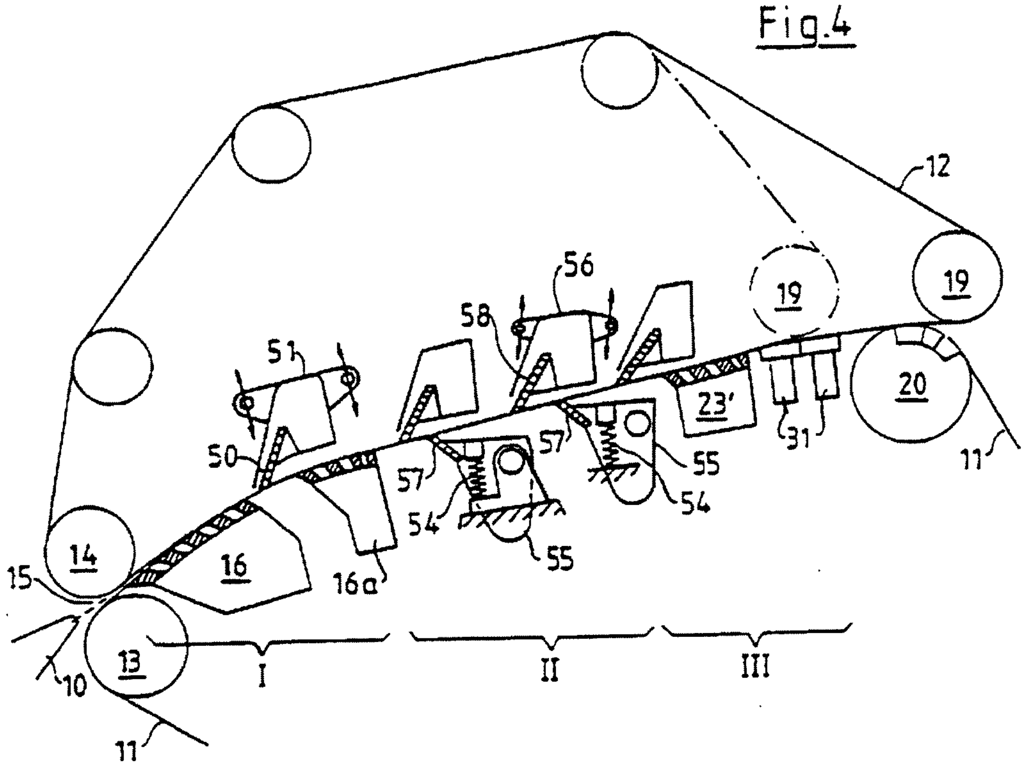
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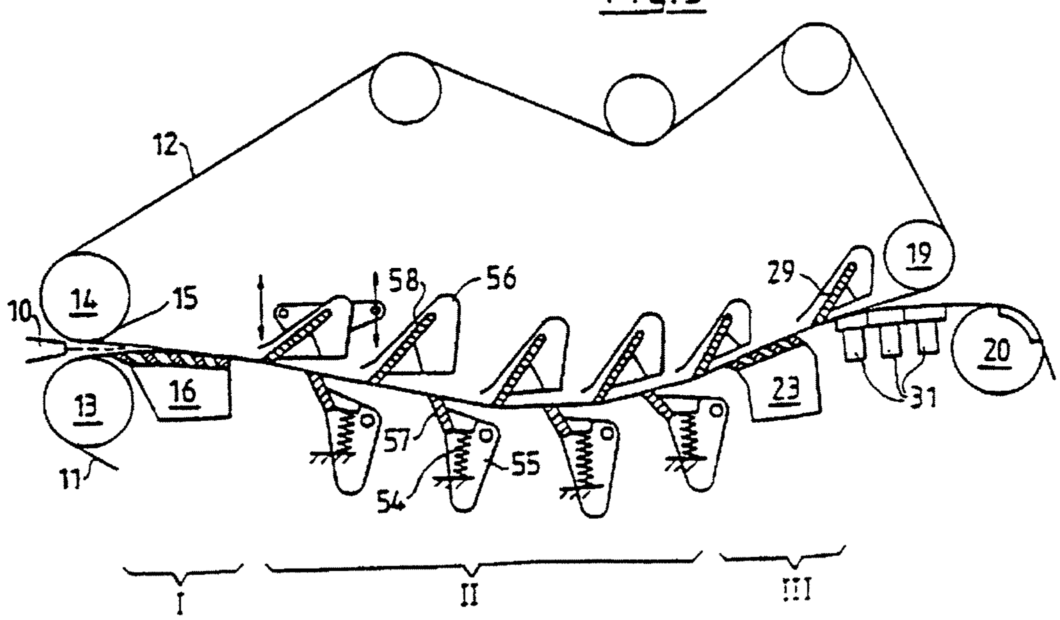
Fig.5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TWIN WIRE FORMER

RELATED APPLICATIONS

This is a continuing application of, and hereby incorporates by reference the entire disclosure of, application Ser. No. 08/286,948, filed Aug. 8, 1994 now U.S. Pat. No. 5,500,091, which is a continuing application Ser. No. 08/055,918, filed Apr. 29, 1993, issued Feb. 14, 1995 as U.S. Pat. No. 5,389,206, which is a continuing application Ser. No. 07/773,965, filed as PCT/EP90/01313 Sep. 8, 1990, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a twin-wire former for the production of a fiber web, in particular a paper web, from a fiber suspension. The invention proceeds from the basis of the twin-wire former known from British Patent 1 125 906. The features indicated in the patent include a twin wire former for producing a fiber web and particularly a paper web from a fiber suspension. Two web forming wire belts, in the form of endless loops, travel together to form a twin wire zone. The web travels between and along the path of the wire belts through the twin wire zone. The twin wire zone has three sections and the elements in those three sections are described below. The patent describes features that state, in other words, that the forming of the fiber web from the pulp suspension fed from the headbox takes place exclusively between two wire belts. Thus, there is no so-called single-wire pre-drainage path. In a first section of the twin-wire zone, the two wire belts together form a wedge-shaped inlet slot; a jet of pulp slurry coming from the headbox discharges into it. The jet strikes the two wire belts at a place where they pass over a curved drainage element; in the case of the aforementioned British patent, this is a stationary, curved forming shoe. Its curved wire guide surface is formed of a plurality of strips with drainage slots between them. This forming shoe is followed (in a second section of the twin-wire zone) by a drainage strip arranged in the other wire loop and, behind the latter, by a drainage strip arranged in the first-mentioned wire loop (and formed by a first suction box). Finally, in a third section of the twin-wire zone there are a plurality of stationary drainage elements developed as flat suction boxes.

It has been attempted for decades with twin-wire formers of the known type to produce fiber webs (in particular, paper webs) of the highest possible quality with relatively high operating speeds. Due to the forming of the web between two wires, the result, in particular, is obtained that the final fiber web has substantially the same properties on both sides (little "two-sidedness"). However, it is difficult to obtain as uniform as possible a distribution of the fibers in the final fiber web. In other words, it is difficult to obtain a good "formation" since while the web is formed, there is always the danger that fibers will agglomerate and form flocculations. Therefore, it is attempted to form a jet of pulp slurry which pulp slurry is as free as possible of flocculations in the headbox (for instance, by means of a turbulence producer). It is, furthermore, endeavored so to influence the drainage of the fiber suspension during the web-forming that "reflocculation" is avoided as far as possible or that, after possible flocculation, a "deflocculation" (i.e. a breaking up of the flocculations) takes place.

It is known that a curved drainage element arranged in the first section of the twin-wire zone and, in particular, a stationary curved forming shoe developed in accordance with the aforementioned British Patent 1 125 906 counteracts the danger of reflocculation. This is true also of the drainage strips arranged in the British patent in the second section of the twin-wire zone. Nevertheless, the danger of reflocculation is not completely eliminated in the arrangement according to said British patent. Since the number of drainage strips there is very small, a large part of the web-forming takes place in the region of the following flat-suction boxes. They, to be sure, are of high drainage capacity so that the web-forming can be completed in the region of the last flat suction boxes (i.e. the so-called main drainage zone, in which a part of the fiber material is still in the form of a suspension, terminates in the region of the flat suction box). The flat suction boxes, however, are not able to avoid reflocculation or to break up flocculations which have already occurred.

In order to control these last-mentioned difficulties, a web-forming device known under the name of "Duoformer D" has been developed (TAPPI proceedings **1988** annual meeting, pages 75 to 80). This known web-forming device is part of a twin-wire former which has a single-wire pre-drainage zone. In the twin-wire zone there are provided, in the one wire loop, a plurality of strips which are fixed in position but adjustably supported, namely, on the bottom of a suction box which drains in upward direction. Furthermore, a plurality of resiliently supported strips are provided in the other wire loop. By this resilience of the last-mentioned strips, the following result can be obtained: For example, upon an increase of the amount of suspension entering between the two wire belts, the flexibly supported strips can move away somewhat. In this way, the danger (which is present when only firmly supported strips are used) is eliminated of a backing up taking place in the fiber suspension in front of the strips. Such a backing up could destroy the fiber layers which have been formed up to then on the two wire belts. In other words, with this known web-forming device, a drainage pressure, once established, remains constant due to the resiliently supported strips even upon a change in the amount of suspension fed or upon a change in the drainage behavior of the fiber suspension. Therefore, automatic adaptation of the web-forming device to said changed conditions occurs.

With this known web-forming device, fiber webs of relatively good formation can also be formed. With respect to this, however, the demands have increased considerably recently, so that further improvements are desirable.

SUMMARY OF THE INVENTION

The object of the invention is so to develop a twin-wire of the aforementioned kind that the quality of the fiber web produced is further improved, particularly with respect to its formation (cloudiness), and that the twin-wire former can easily be adapted to different operating conditions (for instance, with regard to quantity and drainage behavior of the fiber suspension).

This object is achieved by the features set forth below. In particular, there is a respective drainage strip above each of the two wire belts in the second section of the twin wire zone, and at least one of the two drainage strips is supported resiliently against the respective wire belt while the other may or may not be resiliently supported, and typically is rigidly supported against the respective wire belt. Preferably, there are at least two of the drainage strips and often more against each of the wire belts. The drainage strips against one belt are offset along the path of the wire belts with respect to the drainage strips against the other belt, providing a zig zag or staggered array, and the drainage strips against at least one of the belts are resiliently supported.

The inventors have found that a combination of known features, namely:

A. Twin-wire former without a single-wire pre-drainage zone or at least without a single-wire pre-drainage zone of any substantial length such as to cause any appreciable pre-drainage

B. Start of the drainage in the twin-wire zone at a preferably curved drainage element, for instance on a rotating forming cylinder or, even better, on a curved stationary forming shoe

C. Further drainage in the twin-wire zone between strips which are arranged along a "zig-zag" line, the strips which rest against the one wire belt being resiliently supported,

leads to an extremely high increase in the quality of the finished fiber web, so that it satisfies even the highest requirements. At the same time, the twin-wire former of the invention is insensitive to changes in the amount of suspension fed and to changes in the drainage behavior of the fiber suspension. Experiments have shown that it is possible by the invention to obtain both a high increase in quality with respect to the formation and also good values with regard to the retention of fillers and fines. In contradistinction to this, in the known double-wire formers it is constantly found that there is a strong reduction in the retention upon an improvement in the formation.

It was, furthermore, found in experiments that in the second section of the twin-wire zone the number of strips can be considerably reduced as compared with the "Duoformer D". However, this number is substantially greater than in the case of the twin-wire former known from British Patent 1 125 906. It is advantageous to increase the distance between adjacent strips as compared with the "Duoformer D". In particular, the drainage strips above each one of the wire belts are of a thickness along the path of the wire belts and the spacing between adjacent strips above each wire belt is a minimum of about three times the strip thickness.

To be sure, from German OS 31 38 133, FIG. 3, a twin-wire former is known the twin-wire zone of which is provided in a first section with a curved stationary drainage element and in a second section with strips arranged along a "zig-zag" line, which strips may also be resiliently supported and there being a relatively large distance between them. However, in that case, in front of the twin-wire zone there is a single-wire pre-drainage zone in which the forming of the web starts initially only in a lower layer of the fiber suspension fed while the upper layer remains liquid and tends very strongly to flocculation. It has been found that these flakes cannot be broken up again to the desired extent in the following twin-wire zone. Another disadvantage is that the twin-wire zone is diverted by a guide roll (14*b*) behind the second section. This results (due to the so-called table-roll effect) in a further drainage which is uneven over the width of the web and thus in undesired variations in the quality of the web (recognizable, for instance, by disturbing longitudinal stripes).

BRIEF DESCRIPTION OF THE DRAWINGS

Other developments of the invention will be explained below with reference to embodiments which are shown in the drawing. Each of FIGS. 1 to 5 shows-in simplified diagrammatic form-one of the different embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The twin-wire former shown in FIG. 1 has a substantially horizontally extending twin-wire zone; this zone comprises three sections I, II and III arranged one behind the other. The endless wire belts (lower wire **11** and upper wire **12**), shown only in part, travel in the direct vicinity of a headbox **10** over, in each case, a breast roll **13** and **14** respectively, so that the two wire belts together form a wedge-shaped entry slot **15** at the start of the twin-wire zone. The jet pulp discharged by the headbox **10** comes into contact with the two wire belts **11** and **12** only at the place where the lower wire **11** in the first section I of the twin-wire zone travels over a stationary curved forming shoe **16**. The curved travel surface thereof is formed of several strips **16'** with drainage slits present between them. The distance between the two breast rolls **13** and **14** is variable. The forming shoe **16** can be operated with or without vacuum. Additionally, although it is preferable that the forming shoe **16** be curved, a straight forming shoe may also be used in certain situations.

In the second section II of the twin-wire zone, the two wire belts **11** and **12** (with the partially still liquid fiber suspension present between them) travel between a lower drainage box **17** and an upper drainage box **18**. In the lower drainage box **17** there are a row of at least two strips **27** (preferably of approximately rectangular cross section) which are pressed from below resiliently against the lower wire **11**. For this purpose, they are supported, for instance, on springs **24** (or pneumatic pressure cushions) on a, preferably water-permeable, plate. It is obvious that the force of the springs (or of the pressure prevailing in the pressure cushions) is individually adjustable.

The upper drainage box **18** is suspended on both the front and rear ends on vertically displaceable support elements as indicated diagrammatically by double arrows. On its lower side, there is a row of at least three strips **28** of preferably parallelogram cross section which rest against the upper side of the upper wire **12** and are rigidly attached to the box **18**. Above the strips **28**, a front vacuum chamber **21** and a rear vacuum chamber **22** are present in the drainage box **18**.

Each of the upper strips **28** scrapes off water from the wire **12**. Accordingly, the amount of water scraped off decreases in the direction of flow of the wire **12** from strip to strip. The drainage water from each of the strips **28** except the drainage water scraped off by the first strip may be drained away jointly. However, it is disadvantageous to also include the drainage water from the first strip **28** since this generally would disturb the operation of the other strips. Accordingly, a vertical channel **21*a*** is positioned in front of the first upper strip **28** to carry away or collect the water scraped off by the first strip **28**.

In the region of the forming shoe **16**, a part of the water of the fiber suspension is led off downward; another part penetrates due to the tension of the upper wire 12-upwards through the upper wire and is deflected by the furthest in front of the strips **28** into the front vacuum chamber **21**. The water passing upward between the upper strips **28** enters into the rear vacuum chamber **22**. The water penetrating between the lower strips **27** through the lower wire **11** is led off downward. Between adjacent upper drainage strips **28** there is a minimum distance X of about three times the thickness Y of the strips. The same is true of the lower resiliently supported strips **27**. It is important that each of the strips **27** and **28** lies in the region of a space between two opposite strips so that a "zig-zag" arrangement (i.e. non-opposing relationship) is present. Also, as seen in FIG. **1**, the first one of the strips **28** is located upstream of the first one of the strips **27**. The two wires **11** and **12** preferably travel on a straight path through section II. Gentle curvature of this section of the path is, however, also possible; see FIGS. **2** and **5**. Differing from FIG. **1**, the resiliently supported strips

could also be arranged in the upper box **18** and the firmly supported strips in the lower box **17**. In the third section III of the twin-wire zone, both wire belts **11** and **12** travel over another preferably curved forming shoe **23** which (as shown) is arranged preferably in the lower wire loop **11**. Behind it, an additional strip **29** with vacuum chamber **30** can be arranged in the loop of the upper wire **12**. Furthermore, flat suction boxes **31** can be present in the loop of the lower wire. There (as is shown by dash-dot lines) the upper wire **12** can be separated by means of a guide roll **19** from the lower wire **11** and from the fiber web formed. Lower wire and fiber web then travel over a wire suction roll **20**. The guide roll **19** can, however, also lie further back, so that the upper wire **12** is separated from the lower wire **11** only on the wire suction roll **20**.

It is important that two drainage boxes **17** and **18** with the alternately resiliently and firmly supported ledge strips **27** and **28** lie not in the front or the rear sections but in the middle section II of the twin-wire zone, since only here can they develop their full effect, namely, intensive drainage of the fiber suspension fed while retaining the fine flocculation-free fiber distribution. This is achieved in the manner that the corresponding wire belt is imparted a slight (scarcely visible) deflection on each strip so that turbulence is constantly produced in the still liquid part of the fiber pulp. For success it is, however, also decisive that previously, in section I, a known pre-drainage towards both sides has already taken place and that this also takes place with the greatest possible retention of the flocculation-free condition of the fiber suspension.

For this two-sided pre-drainage, a stationary preferably curved forming shoe is provided in the first section I of the twin-wire zone (in accordance with FIGS. **1** and **3–5**) whenever it is a question of satisfying the highest quality demands with respect to the formation. This effect of the forming shoe is due to the fact that at least the one wire belt travels polygonally from strip to strip, each strip not only leading water away but also producing turbulence in the pulp which is still liquid. With such a forming shoe, it is, however, difficult at times to obtain a stable operating condition upon the starting of the paper machine. Therefore, it may be advantageous to provide a known forming roll **40** in accordance with FIG. **2** in Section I instead of the stationary forming shoe and the breast roll lying in front of it. This possibility will be utilized when, in particular, the highest productivity is demanded from the paper manufacturing machine.

In the third section III, the aforementioned strip **29** can serve either solely to lead away water upwards or, in addition, for the further production of turbulence (for further improvement in quality). The latter is possible if a part of the fiber pulp is still in liquid condition at this place.

In FIGS. **1** to **3**, the distance between the two wires **11** and **12** in the twin-wire zone has been shown greatly exaggerated. By this, it is intended to make it clear that the two wires **11** and **12** converge towards each other over a relatively long path within the twin-wire zone. This makes it clear that the process of web-forming on the first forming shoe **16** (in Section I) commences relatively slowly and is completed only in Section III. In this connection, the end of the main drainage zone in which the two wires converge towards each other (and thus, the end of the web-forming process) can lie approximately in the center of the wrapping zone of the second forming shoe **23**, as is indicated, merely by way of example, in FIGS. **1** to **3**. The end of the wire convergence is symbolically indicated there by the point E; the solids content of the paper web has reached there approximately

the value of 8%. This point can, however, also lie, for instance, on one of the flat suction boxes **31**. Behind this point, it is attempted further to increase the solids content, if possible even before the separation of the two wires. One goal is, namely, for the separation of the wires to take place with the highest possible solids content of the web so that as few fibers as possible are torn out of the web upon the separation. The nature and number of the drainage elements necessary for this within the twin-wire zone may, however, differ greatly and is dependent, among other things, on the type of paper and the raw-material components thereof, as well as on the operating speed.

The embodiments shown in FIGS. **2** and **3** differ from the others primarily by the fact that the twin-wire zone rises substantially vertically upward in the direction of travel of the wires. In this way, the removal of the water withdrawn from the fiber suspension is simplified since the water can be discharged relatively uniformly towards both sides. No vacuum chambers are required in particular in the central section II of the twin-wire zone. To be sure, the forming roll **40** of FIG. **2** is, as a rule, developed as a suction roll. The forming shoes **16**, **23**, particularly those arranged in the third section III, can, if necessary, be provided with a suction device.

Further elements of the twin-wire former shown in FIG. **2** are water-collection containers **41**, **42** and **43**, guide plates **44** associated with the fixed strips **28**, and a water removal strip **45**. The other elements are provided with the same reference numbers as the corresponding elements in FIG. **1**. The same is true with regard to FIG. **3**. One possible modification of FIG. **3** can consist therein that, instead of the wire suction roll **20**, a forming roll is provided, and instead of the guide roll **19** the wire suction roll. A similar arrangement is known from German Utility Model 88 06 036 (Voith File: P 4539). Aside from this exception and aside from the embodiment according to FIG. **2** (with forming roll **40**), the invention will, however, be used whenever possible-so to design the twin-wire former that the relatively expensive forming roll (as to purchase and operation) can be dispensed with. Thus, as a rule, the wire suction roll **20** is present as the sole suction roll. Furthermore, in all embodiments of the invention it can be seen to it that no guide roll which deflects the twin-wire zone (and has the above-mentioned injurious table-roll effect) is present.

The embodiment of FIG. **4** differs from FIG. **1** among other things by the fact that, in the first section I of the twin-wire zone, a second curved stationary forming shoe **16a** is arranged in the loop of the lower wire **11** behind and spaced from a first curved stationary forming shoe **16**. Furthermore, in the loop of the upper wire **12** in the region between the two stationary forming shoes **16** and **16a** there is provided an individual strip **50** which in known manner is part of a vacuum chamber **51**. This vacuum chamber **51**, similar to the upper drainage box **18** of FIG. **1**, is suspended on its front and rear ends in vertically displaceable mounts. In this way, both the depth of penetration of the strip **50** into the path of travel of the upper wire **12** as well as the angle of attack of the strip **50** can be varied. With slight depth of penetration, the strip **50** serves solely for removal of water, while with greater depth of penetration it serves, in addition, for the production of turbulence in the suspension and, thus, for improvement of the formation. By the presence of two separate forming shoes **16** and **16a**, the pre-drainage on both sides is temporarily interrupted; it is only continued after the strip **50** has removed from the upper wire **12** the water which has penetrated upward on the first forming shoe **16**. In this way, higher operating speeds are possible.

Another difference from FIG. 1 is that, in the second section II of the twin-wire zone, the lower, flexibly supported strips 57 and the upper, firmly supported strips 58 are developed as individual strips. This means that each strip has its own supporting body 55/56. The lower strip-supporting bodies 55 are swingably mounted, the strip 57 being pressed resiliently by the force of springs 54 against the bottom of the lower wire 11. The supporting body 56 of each of the upper strips 58 is developed as vacuum chamber in the same way as that of the strip 50. The suspension of these vacuum chambers 56 corresponds to that of the vacuum chamber 51. It is important that each of the strips 57 and 58 rest with a given force of application (corresponding to the suspension pressure) against its wire belt 11 or 12. The strips 57 and 58 are adjusted in such a manner that a slight deflection of the wire belts takes place preferably on each strip. Due to the resilient supporting of the lower strips 57, the adjustment, once effected, is insensitive to changes in the quantity or quality of pulp, so that no backing up takes place in front of the strips and, nevertheless, an effective introduction of turbulence forces into the fiber suspension takes place. In contradistinction to FIGS. 1 to 3, there is the possibility of adjusting each one of the strips 57/58 individually with respect to position in height and inclination relative to the travel path of the wire. In this way, one can even better control the quality of the paper produced, with respect to both the formation and the nature of its surface (printability). Differing from FIG. 4, the upper strips 58 could be supported resiliently and the lower strips 57 stationary. Another alternative could consist therein that not only the upper strips 58 but also the lower strips 57 are fastened in vertically displaceable mounts (as shown on the vacuum chamber 51). In such case, the springs 54 might possibly be eliminated.

Another difference between FIGS. 1 and 4 resides in the fact that in FIG. 4 the twin-wire zone rises in the direction of travel of the wires upwards with an inclination of, on the average, about 20° with respect to the horizontal. In this way, it is possible to keep the entire height of the twin-wire former relatively slight. In the third section III of the twin-wire zone, a flat forming shoe 23' is provided rather than a curved one, differing from FIG. 1. The separation of the upper wire 12 from the lower wire and the fiber web formed can take place, as in FIG. 1, on one of the flat suction boxes 31. Instead of this, however, the upper wire 12 can also be conducted up to the wire suction roll 20. There, as shown, it can wrap around a small part (or, alternatively, a larger part) of the circumference of the wire suction roll and then be returned via the reversing roll 19.

In the embodiment shown in FIG. 5, the twin-wire zone, as a whole, extends substantially in horizontal direction. The individual elements are substantially the same as in the embodiment of FIG. 4. However, there is the difference that the drainage strips 57 and 58 lying in the second section II of the twin-wire zone are arranged along a downwardly curved path of the twin-wire zone. Accordingly, an upwardly curved forming shoe 16, 23 is provided in the first section I and in the third section III of the twin-wire zone. This embodiment is advisable, in particular, for the modernizing of existing Fourdrinier paper machines.

The embodiments shown have the feature in common that, in the second section II of the twin-wire zone, there are present preferably n flexibly supported strips 27/57 and n+1 rigidly supported strips. However, it is also possible to make the number of flexibly supported strips equal to or greater by one than the number of rigidly supported strips. Instead of a rigidly supported strip, a feed or discharge edge of a drainage box can also be provided. The minimum number n of flexibly supported strips is two (see FIG. 4). However, three or four flexibly supported strips are preferred.

What is claimed is:

1. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts, means for directing the wire belts to travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a first drainage element at the start of the path through the twin wire zone, means for supporting the belts for forming a wedge shaped entrance slot into the first section, a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

the twin wire zone having a second section following the first section along the path of the belts through the twin wire zone in the second section, a plurality of first drainage strips are positioned for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; first support means for resiliently supporting the first drainage strips against the respective wire belt that the strips contact;

second support means supporting the second drainage strips rigidly against the second wire belt;

first means for collecting the water drained from the fiber suspension by the most upstream, one of the drainage strips;

second means separate from the first means for collecting the water drained from the fiber suspension by all of the other drainage strips; and

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; a second drainage element in the third section for being engaged by one of the wire belts as the wire belts travel over the second drainage element, the twin wire zone being free of rolls which deflect the twin wire zone.

2. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts, means for directing the wire belts to travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a first drainage element at the start of the path through the twin wire zone, means for supporting the belts for forming a wedge shaped entrance slot into the first section, a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber sus-

pension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

the twin wire zone having a second section following the first section along the path of the belts through the twin wire zone; in the second section, a plurality of first drainage strips are positioned for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; first support means for resiliently supporting the first drainage strips against the respective ware belt that the strips contact;

second support means supporting the second drainage strips rigidly against the second wire belt;

first means for collecting the water drained from the fiber suspension by the most upstream one of the drainage strips;

second means separate from the first means for collecting the water drained from the fiber suspension by all of the other drainage strips; and

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone: a second drainage element in the third section for being engaged by one of the wire belts as the wire belts travel over the second drainage element, the twin wire zone being free of any forming rolls.

3. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts, means for directing the wire belts to travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a first drainage element at the start of the path through the twin wire zone, means for supporting the belts for forming a wedge shaped entrance slot into the first section, a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

the twin wire zone having a second section following the first section along the path of the belts through the twin wire zone; in the second section, a plurality of first drainage strips are positioned within the loop of the first wire belt and are for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; first support means for resiliently supporting the first drainage strips against the respective wire belt that the strips contact, the last one of the second drainage strips being located downstream of the last one of the first drainage strips;

second support means supporting the second drainage strips rigidly against the second wire belt;

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; a second drainage element in the third section for being engaged by one of the wire belts as the wire belts travel over the second drainage element, the second drainage element having an open surface to enable water to be drained through the wire belt in contact therewith; and

the twin wire zone being free of rolls which deflect the twin wire zone.

4. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts, means for directing the wire belts to travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a first drainage element at the start of the path through the twin wire zone, means for supporting the belts for forming a wedge shaped entrance slot into the first section, a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

the twin wire zone having a second section following the first section along the path of the belts through the twin wire zone; in the second section, a plurality of first drainage strips are positioned within the loop of the first wire belt and are for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; first support means for resiliently supporting the first drainage strips against the respective wire belt that the strips contact, the last one of the second drainage strips being located downstream of the last one of the first drainage strips;

second support means supporting the second drainage strips rigidly against the second wire belt;

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; a second drainage element in the third section for being engaged by one of the wire belts as the wire belts travel over the second drainage element; and

the twin wire zone being free of any forming rolls.

5. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts, means for directing the wire belts to travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a single first drainage element at the start of the path

through the twin wire zone, means for supporting the belts for forming a wedge shaped entrance slot into the first section, a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone; said single first drainage element in the first section being a single forming roll having an open surface to enable drainage of water from the fiber suspension and being curved along the path of the belts through the twin wire zone, the single forming roll being engaged by one of the wire belts for curving the path of the belts around the single forming roll after the entrance of the suspension into the entrance slot;

the twin wire zone having a second section following the first section along the path of the belts through the twin wire zone; in the second section, a plurality of first drainage strips are positioned within the loop of the first wire belt and are for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts

with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; first support means for resiliently supporting the first drainage strips against the respective wire belt that the strips contact;

second support means supporting the second drainage strips rigidly against the second wire belt; and

means for supplying a vacuum in the area of the second drainage strips;

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; a second drainage element in the third section, for being engaged by one of the wire belts as the wire belts travel over the second drainage element, the second drainage element having an open surface to enable water to be drained through the wire belt in contact therewith; and

the twin wire zone apart from said single forming roll being free of rolls which deflect the twin wire zone.

* * * * *

EXHIBIT 2

US005972168A

United States Patent [19]

Egelhof et al.

[11] **Patent Number: 5,972,168**

[45] **Date of Patent: Oct. 26, 1999**

[54] **TWIN WIRE FORMER**

[75] Inventors: **Dieter Egelhof**; **Klaus Henseler**, both of Heidenheim, Germany; **Werner Kade**, Neenah, Wis.; **Albrecht Meinecke**, Heidenheim, Germany; **Wilhelm Wanke**, Heidenheim, Germany; **Hans-Jurgen Wulz**, Heidenheim, Germany; **Rudolf Bück**, deceased, late of Heidenheim, Germany, by Elsie Bück, legal representative

[73] Assignee: **Voith Sulzer Papiertechnik Patent GmbH**, Germany

[21] Appl. No.: **09/161,138**

[22] Filed: **Sep. 25, 1998**

Related U.S. Application Data

[62] Continuation of application No. 09/023,435, Feb. 13, 1998, which is a continuation of application No. 08/556,769, Nov. 2, 1995, Pat. No. 5,718,805, which is a continuation of application No. 08/286,948, Aug. 8, 1994, Pat. No. 5,500,091, which is a continuation of application No. 08/055,918, Apr. 29, 1993, Pat. No. 5,389,206, which is a continuation of application No. 07/773,965, abandoned, filed as application No. PCT/EP90/01313, Sep. 8, 1990.

[51] **Int. Cl.**[6] **D21F 1/00**

[52] **U.S. Cl.** **162/203**; 162/301

[58] **Field of Search** 162/203, 300, 162/301, 303, 348, 352

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Primary Examiner—Karen M. Hastings
Attorney, Agent, or Firm—Ostrolenk, Faber, Gerb & Soffen, LLP

[57] **ABSTRACT**

In a twin-wire former for the production of a paper web, two wire belts (**11** and **12**) together form a twin-wire zone which is divided into three sections (I, II and III). In the first section (I) the two wires (**11**, **12**) travel over a curved forming shoe (**16**). They form there a wedge-shaped inlet slot (**15**) with which a headbox (**10**) is directly associated. In the second section (II), several resiliently supported strips (**27**) rest against the lower wire (**11**) and between each of said strips (**27**) a rigidly mounted strip (**28**) rests against the upper wire (**12**). In the third section (III) both wire belts (**11**, **12**) pass over another curved forming shoe (**23**).

8 Claims, 2 Drawing Sheets

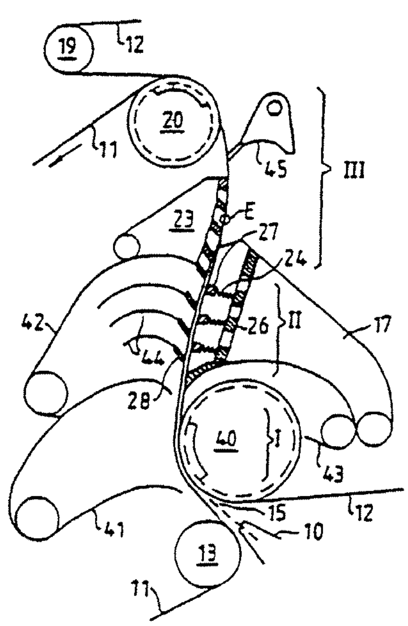


Fig.1

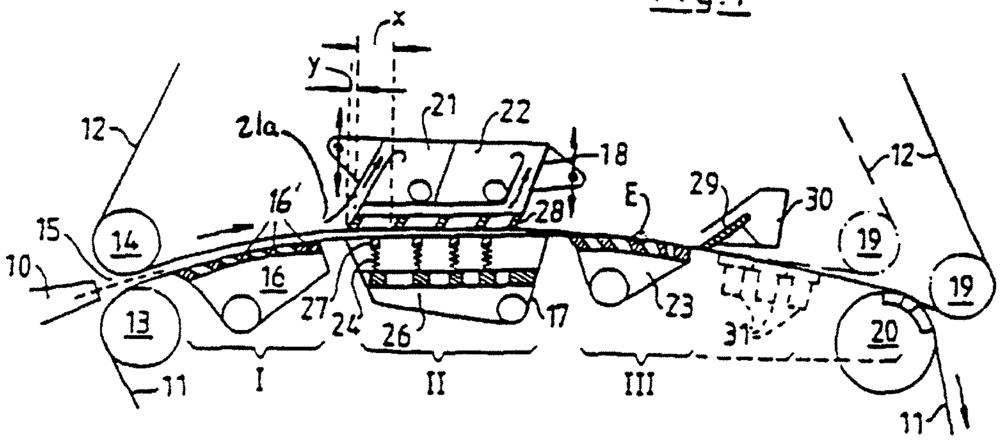


Fig.2

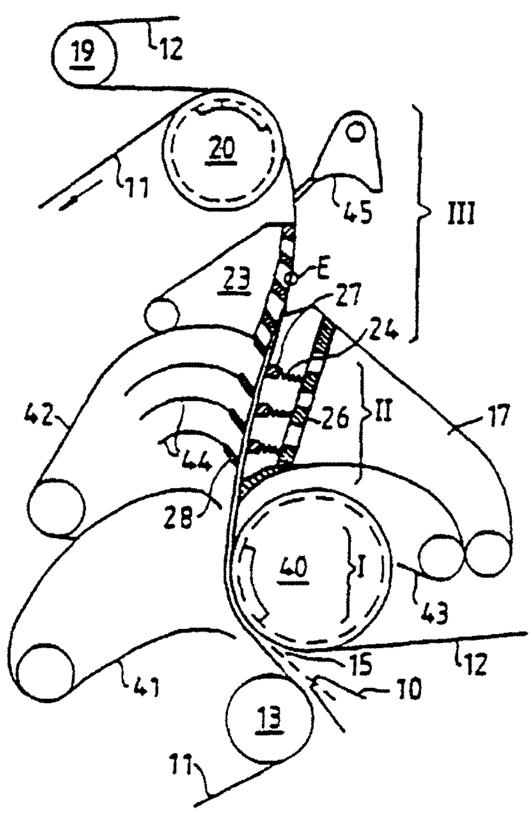


Fig.3

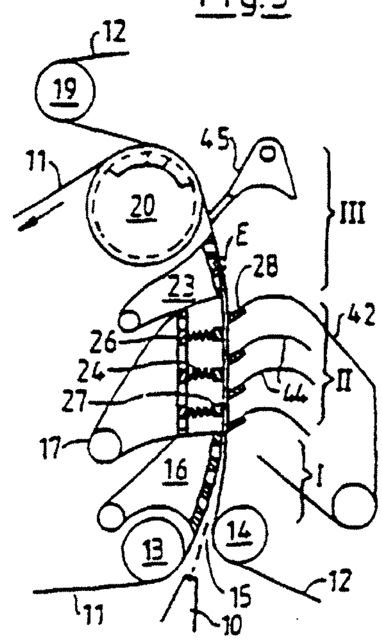
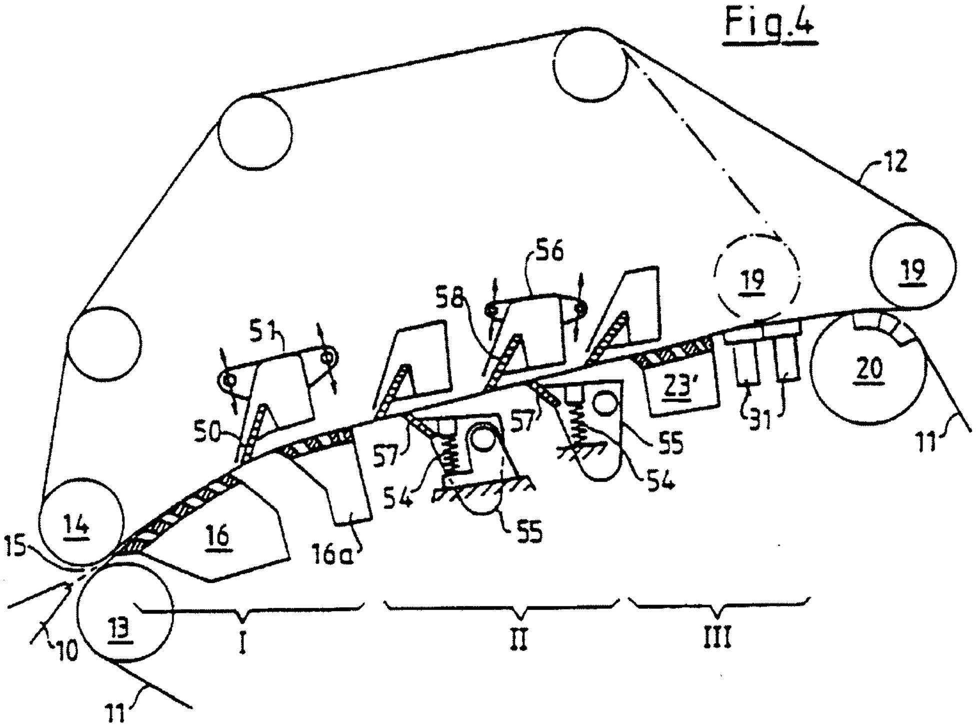


Fig.4



12
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11
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58
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23'
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54
55
14
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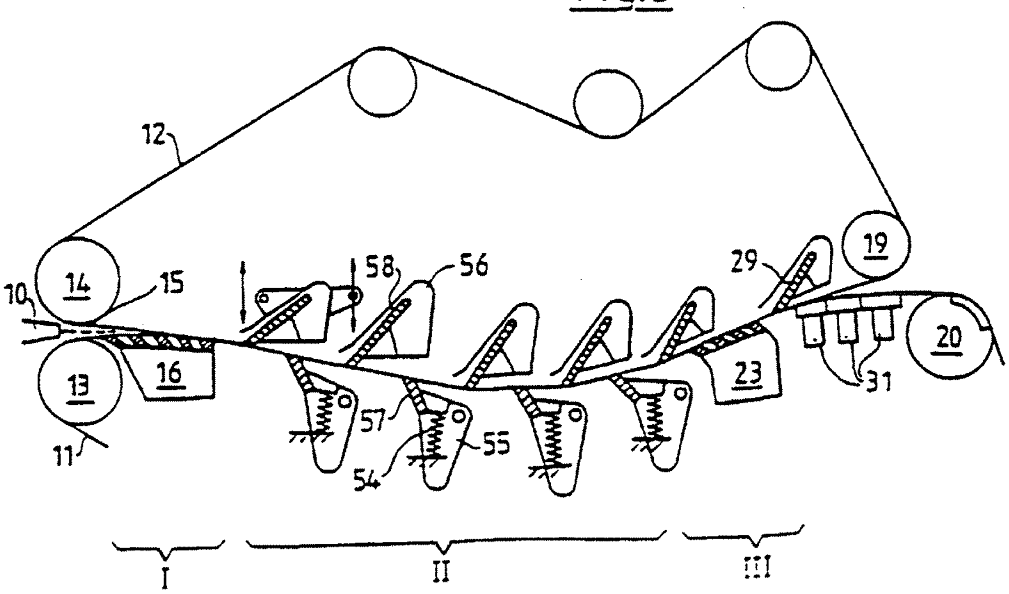
16
16a
13
10
11
I
II
III

Fig.5



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TWIN WIRE FORMER

RELATED APPLICATIONS

This is a continuing application of, and hereby incorporates by reference the entire disclosure of, application Ser. No. 09/023,435, filed Feb. 13, 1998, allowed, which is a continuing application of Ser. No. 08/556,769, filed Nov. 2, 1995, now Pat. No. 5,718,805, which is a continuing application of Ser. No. 08/286,948, filed Aug. 8, 1994, now Pat. No. 5,500,091, which is a continuing application of Ser. No. 08/055,918, filed Apr. 29, 1993, now Pat. No. 5,389,206, which is a continuing application of Ser. No. 07/773,965, filed Nov. 12, 1991, now abandoned, filed as PCT/EP90/01313 on Sept. 8, 1990, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a twin-wire former for the production of a fiber web, in particular a paper web, from a fiber suspension. The invention proceeds from the basis of the twin-wire former known from British Patent 1 125 906. The features indicated in the patent include a twin wire former for producing a fiber web and particularly a paper web from a fiber suspension. Two web forming wire belts, in the form of endless loops, travel together to form a twin wire zone. The web travels between and along the path of the wire belts through the twin wire zone. The twin wire zone has three sections and the elements in those three sections are described below. The patent describes features that state, in other words, that the forming of the fiber web from the pulp suspension fed from the headbox takes place exclusively between two wire belts. Thus, there is no so-called single-wire pre-drainage path. In a first section of the twin-wire zone, the two wire belts together form a wedge-shaped inlet slot; a jet of pulp slurry coming from the headbox discharges into-it. The jet strikes the two wire belts at a place where they pass over a curved drainage element; in the case of the aforementioned British patent, this is a stationary, curved forming shoe. Its curved wire guide surface is formed of a plurality of strips with drainage slots between them. This forming shoe is followed (in a second section of the twin-wire zone) by a drainage strip arranged in the other wire loop and, behind the latter, by a drainage strip arranged in the first-mentioned wire loop (and formed by a first suction box). Finally, in a third section of the twin-wire zone there are a plurality of stationary drainage elements developed as flat suction boxes.

It has been attempted for decades with twin-wire farmers of the known type to produce fiber webs (in particular, paper webs) of the highest possible quality with relatively high operating speeds. Due to the forming of the web between two wires, the result, in particular, is obtained that the final fiber web has substantially the same properties on both sides (little "two-sidedness"). However, it is difficult to obtain as uniform as possible a distribution of the fibers in the final fiber web. In other words, it is difficult to obtain a good "formation" since while the web is formed, there is always the danger that fibers will agglomerate and form flocculations. Therefore, it is attempted to form a jet of pulp slurry which pulp slurry is as free as possible of flocculations in the headbox (for instance, by means of a turbulence producer). It is, furthermore, endeavored so to influence the drainage of the fiber suspension during the web-forming that "reflocculation" is avoided as far as possible or that, after possible flocculation, a "deflocculation" (i.e. a breaking up of the flocculations) takes place.

It is known that a curved drainage element arranged in the first section of the twin-wire zone and, in particular, a stationary curved forming shoe developed in accordance with the aforementioned British Patent 1 125 906 counteracts the danger of reflocculation. This is true also of the drainage strips arranged in the British Patent in the second section of the twin-wire zone. Nevertheless, the danger of reflocculation is not completely eliminated in the arrangement according to said British Patent. Since the number of drainage strips there is very small, a large part of the web-forming takes place in the region of the following flat-suction boxes. They, to be sure, are of high drainage capacity so that the web-forming can be completed in the region of the last flat suction boxes (i.e. the so-called main drainage zone, in which a part of the fiber material is still in the form of a suspension, terminates in the region of the flat suction box). The flat suction boxes, however, are not able to avoid reflocculation or to break up flocculations which have already occurred.

In order to control these last-mentioned difficulties, a web-forming device known under the name of "Duoformer D" has been developed (TAPPI Proceedings 1988 annual meeting, pages 75 to 80). This known web-forming device is part of a twin-wire former which has a single-wire pre-drainage zone. In the twin-wire zone there are provided, in the one wire loop, a plurality of strips which are fixed in position but adjustably supported, namely, on the bottom of a suction box which drains in upward direction. Furthermore, a plurality of resiliently supported strips are provided in the other wire loop. By this resilience of the last-mentioned strips, the following result can be obtained: For example, upon an increase of the amount of suspension entering between the two wire belts, the flexibly supported strips can move away somewhat. In this way, the danger (which is present when only firmly supported strips are used) is eliminated of a backing up taking place in the fiber suspension in front of the strips. Such a backing up could destroy the fiber layers which have been formed up to then on the two wire belts. In other words, with this known web-forming device, a drainage pressure, once established, remains constant due to the resiliently supported strips even upon a change in the amount of suspension fed or upon a change in the drainage behavior of the fiber suspension. Therefore, automatic adaptation of the web-forming device to said changed conditions occurs.

With this known web-forming device, fiber webs of relatively good formation can also be formed. With respect to this, however, the demands have increased considerably recently, so that further improvements are desirable.

SUMMARY OF THE INVENTION

The object of the invention is so to develop a twin-wire of the aforementioned kind that the quality of the fiber web produced is further improved, particularly with respect to its formation (cloudiness), and that the twin-wire former can easily be adapted to different operating conditions (for instance, with regard to quantity and drainage behavior of the fiber suspension).

This object is achieved by the features set forth below in particular, there is a respective drainage strip above each of the two wire belts in the second section of the twin wire zone, and at least one of the two drainage strips is supported resiliently against the respective wire belt while the other may or may not be resiliently supported, and typically is rigidly supported against the respective wire belt. Preferably, there are at least two of the drainage strips and often more against each of the wire belts. The drainage strips against one belt are offset along the path of the wire belts with

respect to the drainage strips against the other belt, providing a zig zag or staggered array, and the drainage strips against at least one of the belts are resiliently supported.

The inventors have found that a combination of known features, namely:

A. Twin-wire former without a single-wire pre-drainage zone or at least without a single-wire pre-drainage zone of any substantial length such as to cause any appreciable pre-drainage

B. Start of the drainage in the twin-wire zone at a preferably curved drainage element, for instance on a rotating forming cylinder or, even better, on a curved stationary forming shoe

C. Further drainage in the twin-wire zone between strips which are arranged along a "zig-zag" line, the strips which rest against the one wire belt being resiliently supported, leads to an extremely high increase in the quality of the finished fiber web, so that it satisfies even the highest requirements. At the same time, the twin-wire former of the invention is insensitive to changes in the amount of suspension fed and to changes in the drainage behavior of the fiber suspension. Experiments have shown that it is possible by the invention to obtain both a high increase in quality with respect to the formation and also good values with regard to the retention of fillers and fines. In contradistinction to this, in the known double-wire formers it is constantly found that there is a strong reduction in the retention upon an improvement in the formation.

It was, furthermore, found in experiments that in the second section of the twin-wire zone the number of strips can be considerably reduced as compared with the "Duoformer D". However, this number is substantially greater than in the case of the twin-wire former known from British Patent 1 125 906. It is advantageous to increase the distance between adjacent strips as compared with the "Duoformer D". In particular, the drainage strips above each one of the wire belts are of a thickness along the path of the wire belts and the spacing between adjacent strips above each wire belt is a minimum of about three times the strip thickness.

To be sure, from German OS 31 38 133, FIG. 3, a twin-wire former is known the twin-wire zone of which is provided in a first section with a curved stationary drainage element and in a second section with strips arranged along a "zig-zag" line, which strips may also be resiliently supported and there being a relatively large distance between them. However, in that case, in front of the twin-wire zone there is a single-wire pre-drainage zone in which the forming of the web starts initially only in a lower layer of the fiber suspension fed while the upper layer remains liquid and tends very strongly to flocculation. It has been found that these flakes cannot be broken up again to the desired extent in the following twin-wire zone. Another disadvantage is that the twin-wire zone is diverted by a guide roll (**14***b*) behind the second section. This results (due to the so-called table-roll effect) in a further drainage which is uneven over the width of the web and thus in undesired variations in the quality of the web (recognizable, for instance, by disturbing longitudinal stripes).

BRIEF DESCRIPTION OF THE DRAWINGS

Other developments of the invention will be explained below with reference to embodiments which are shown in the drawing. Each of FIGS. **1** to **5** shows-in simplified diagrammatic form-one of the different embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The twin-wire former shown in FIG. **1** has a substantially horizontally extending twin-wire zone; this zone comprises three sections I, II and III arranged one behind the other. The endless wire belts (lower wire **11** and upper wire **12**), shown only in part, travel in the direct vicinity of a headbox **10** over, in each case, a breast roll **13** and **14** respectively, so that the two wire belts together form a wedge-shaped entry slot **15** at the start of the twin-wire zone. The jet pulp discharged by the headbox **10** comes into contact with the two wire belts **11** and **12** only at the place where the lower wire **11** in the first section I of the twin-wire zone travels over a stationary curved forming shoe **16**. The curved travel surface thereof is formed of several strips **16'** with drainage slits present between them. The distance between the two breast rolls **13** and **14** is variable. The forming shoe **16** can be operated with or without vacuum. Additionally, although it is preferable that the forming shoe **16** be curved, a straight forming shoe may also be used in certain situations.

In the second section II of the twin-wire zone, the two wire belts **11** and **12** (with the partially still liquid fiber suspension present between them) travel between a lower drainage box **17** and an upper drainage box **18**. In the lower drainage box **17** there are a row of at least two strips **27** (preferably of approximately rectangular cross section) which are pressed from below resiliently against the lower wire **11**. For this purpose, they are supported, for instance, on springs **24** (or pneumatic pressure cushions) on a, preferably water-permeable, plate. It is obvious that the force of the springs (or of the pressure prevailing in the pressure cushions) is individually adjustable.

The upper drainage box **18** is suspended on both the front and rear ends on vertically displaceable support elements as indicated diagrammatically by double arrows. On its lower side, there is a row of at least three strips **28** of preferably parallelogram cross section which rest against the upper side of the upper wire **12** and are rigidly attached to the box **18**. Above the strips **28**, a front vacuum chamber **21** and a rear vacuum chamber **22** are present in the drainage box **18**.

Each of the upper strips **28** scrapes off water from the wire **12**. Accordingly, the amount of water scraped off decreases in the direction of flow of the wire **12** from strip to strip. The drainage water from each of the strips **28** except the drainage water scraped off by the first strip may be drained away jointly. However, it is disadvantageous to also include the drainage water from the first strip **28** since this generally would disturb the operation of the other strips. Accordingly, a vertical channel **21***a* is positioned in front of the first upper strip **28** to carry away or collect the water scraped off by the first strip **28**.

In the region of the forming shoe **16**, a part of the water of the fiber suspension is led off downward; another part penetrates due to the tension of the upper wire **12**-upwards through the upper wire and is deflected by the furthest in front of the strips **28** into the front vacuum chamber **21**. The water passing upward between the upper strips **28** enters into the rear vacuum chamber **22**. The water penetrating between the lower strips **27** through the lower wire **11** is led off downward. Between adjacent upper drainage strips **28** there is a minimum distance X of about three times the thickness Y of the strips. The same is true of the lower resiliently supported strips **27**. It is important that each of the strips **27** and **28** lies in the region of a space between two opposite strips so that a "zig-zag" arrangement (i.e. non-opposing relationship) is present. Also, as seen in FIG. **1**, the first one of the strips **28** is located upstream of the first one of the strips **27**. The two wires **11** and **12** preferably travel on a straight path through section II. Gentle curvature of this section of the path is, however, also possible; see FIGS. **2** and **5**. Differing from FIG. **1**, the resiliently supported strips

could also be arranged in the upper box **18** and the firmly supported strips in the lower box **17**. In the third section III of the twin-wire zone, both wire belts **11** and **12** travel over another preferably curved forming shoe **23** which (as shown) is arranged preferably in the lower wire loop **11**. Behind it, an additional strip **29** with vacuum chamber **30** can be arranged in the loop of the upper wire **12**. Furthermore, flat suction boxes **31** can be present in the loop of the lower wire. There (as is shown by dash-dot lines) the upper wire **12** can be separated by means of a guide roll **19** from the lower wire **11** and from the fiber web formed. Lower wire and fiber web then travel over a wire suction roll **20**. The guide roll **19** can, however, also lie further back, so that the upper wire **12** is separated from the lower wire **11** only on the wire suction roll **20**.

It is important that two drainage boxes **17** and **18** with the alternately resiliently and firmly supported ledge strips **27** and **28** lie not in the front or the rear sections but in the middle section II of the twin-wire zone, since only here can they develop their full effect, namely, intensive drainage of the fiber suspension fed while retaining the fine flocculation-free fiber distribution. This is achieved in the manner that the corresponding wire belt is imparted a slight (scarcely visible) deflection on each strip so that turbulence is constantly produced in the still liquid part of the fiber pulp. For success it is, however, also decisive that previously, in section I, a known pre-drainage towards both sides has already taken place and that this also takes place with the greatest possible retention of the flocculation-free condition of the fiber suspension.

For this two-sided pre-drainage, a stationary preferably curved forming shoe is provided in the first section I of the twin-wire zone (in accordance with FIGS. **1** and **3–5**) whenever it is a question of satisfying the highest quality demands with respect to the formation. This effect of the forming shoe is due to the fact that at least the one wire belt travels polygonally from strip to strip, each strip not only leading water away but also producing turbulence in the pulp which is still liquid. With such a forming shoe, it is, however, difficult at times to obtain a stable operating condition upon the starting of the paper machine. Therefore, it may be advantageous to provide a known forming roll **40** in accordance with FIG. **2** in Section I instead of the stationary forming shoe and the breast roll lying in front of it. This possibility will be utilized when, in particular, the highest productivity is demanded from the paper manufacturing machine.

In the third section III, the aforementioned strip **29** can serve either solely to lead away water upwards or, in addition, for the further production of turbulence (for further improvement in quality). The latter is possible if a part of the fiber pulp is still in liquid condition at this place.

In FIGS. **1** to **3**, the distance between the two wires **11** and **12** in the twin-wire zone has been shown greatly exaggerated. By this, it is intended to make it clear that the two wires **11** and **12** converge towards each other over a relatively long path within the twin-wire zone. This makes it clear that the process of web-forming on the first forming shoe **16** (in Section I) commences relatively slowly and is completed only in Section III. In this connection, the end of the main drainage zone in which the two wires converge towards each other (and thus, the end of the web-forming process) can lie approximately in the center of the wrapping zone of the second forming shoe **23**, as is indicated, merely by way of example, in FIGS. **1** to **3**. The end of the wire convergence is symbolically indicated there by the point E; the solids content of the paper web has reached there approximately

the value of 8%. This point can, however, also lie, for instance, on one of the flat suction boxes **31**. Behind this point, it is attempted further to increase the solids content, if possible even before the separation of the two wires. One goal is, namely, for the separation of the wires to take place with the highest possible solids content of the web so that as few fibers as possible are torn out of the web upon the separation. The nature and number of the drainage elements necessary for this within the twin-wire zone may, however, differ greatly and is dependent, among other things, on the type of paper and the raw-material components thereof, as well as on the operating speed.

The embodiments shown in FIGS. **2** and **3** differ from the others primarily by the fact that the twin-wire zone rises substantially vertically upward in the direction of travel of the wires. In this way, the removal of the water withdrawn from the fiber suspension is simplified since the water can be discharged relatively uniformly towards both sides. No vacuum chambers are required in particular in the central section II of the twin-wire zone. To be sure, the forming roll **40** of FIG. **2** is, as a rule, developed as a suction roll. The forming shoes **16**, **23**, particularly those arranged in the third section III, can, if necessary, be provided with a suction device.

Further elements of the twin-wire former shown in FIG. **2** are water-collection containers **41**, **42** and **43**, guide plates **44** associated with the fixed strips **28**, and a water removal strip **45**. The other elements are provided with the same reference numbers as the corresponding elements in FIG. **1**. The same is true with regard to FIG. **3**. One possible modification of FIG. **3** can consist therein that, instead of the wire suction roll **20**, a forming roll is provided, and instead of the guide roll **19** the wire suction roll. A similar arrangement is known from German Utility Model 88 06 036 (Voith File: P 4539). Aside from this exception and aside from the embodiment according to FIG. **2** (with forming roll **40**), the invention will, however, be used whenever possible-so to design the twin-wire former that the relatively expensive forming roll (as to purchase and operation) can be dispensed with. Thus, as a rule, the wire suction roll **20** is present as the sole suction roll. Furthermore, in all embodiments of the invention it can be seen to it that no guide roll which deflects the twin-wire zone (and has the above-mentioned injurious table-roll effect) is present.

The embodiment of FIG. **4** differs from FIG. **1** among other things by the fact that, in the first section I of the twin-wire zone, a second curved stationary forming shoe **16***a* is arranged in the loop of the lower wire **11** behind and spaced from a first curved stationary forming shoe **16**. Furthermore, in the loop of the upper wire **12** in the region between the two stationary forming shoes **16** and **16***a* there is provided an individual strip **50** which in known manner is part of a vacuum chamber **51**. This vacuum chamber **51**, similar to the upper drainage box **18** of FIG. **1**, is suspended on its front and rear ends in vertically displaceable mounts. In this way, both the depth of penetration of the strip **50** into the path of travel of the upper wire **12** as well as the angle of attack of the strip **50** can be varied. With slight depth of penetration, the strip **50** serves solely for removal of water, while with greater depth of penetration it serves, in addition, for the production of turbulence in the suspension and, thus, for improvement of the formation. By the presence of two separate forming shoes **16** and **16***a*, the pre-drainage on both sides is temporarily interrupted; it is only continued after the strip **50** has removed from the upper wire **12** the water which has penetrated upward on the first forming shoe **16**. In this way, higher operating speeds are possible.

Another difference from FIG. **1** is that, in the second section II of the twin-wire zone, the lower, flexibly supported strips **57** and the upper, firmly supported strips **58** are developed as individual strips. This means that each strip has its own supporting body **55/56**. The lower strip-supporting bodies **55** are swingably mounted, the strip **57** being pressed resiliently by the force of springs **54** against support bottom of the lower wire **11**. The supporting body **56** of each of the upper strips **58** is developed as vacuum chamber in the same way as that of the strip **50**. The suspension of these vacuum chambers **56** corresponds to that of the vacuum chamber **51**. It is important that each of the strips **57** and **58** rest with a given force of application (corresponding to the suspension pressure) against its wire belt **11** or **12**. The strips **57** and **58** are adjusted in such a manner that a slight deflection of the wire belts takes place preferably on each strip. Due to the resilient supporting of the lower strips **57**, the adjustment, once effected, is insensitive to changes in the quantity or quality of pulp, so that no backing up takes place in front of the strips and, nevertheless, an effective introduction of turbulence forces into the fiber suspension takes place. In contradistinction to FIGS. **1** to **3**, there is the possibility of adjusting each one of the strips **57/58** individually with respect to position in height and inclination relative to the travel path of the wire. In this way, one can even better control the quality of the paper produced, with respect to both the formation and the nature of its surface (printability). Differing from FIG. **4**, the upper strips **58** could be supported resiliently and the lower strips **57** stationary. Another alternative could consist therein that not only the upper strips **58** but also the lower strips **57** are fastened in vertically displaceable mounts (as shown on the vacuum chamber **51**). In such case, the springs **54** might possibly be eliminated.

Another difference between FIGS. **1** and **4** resides in the fact that in FIG. **4** the twin-wire zone rises in the direction of travel of the wires upwards with an inclination of, on the average, about 20° with respect to the horizontal. In this way, it is possible to keep the entire height of the twin-wire former relatively slight. In the third section III of the twin-wire zone, a flat forming shoe **23'** is provided rather than a curved one, differing from FIG. **1**. The separation of the upper wire **12** from the lower wire and the fiber web formed can take place, as in FIG. **1**, on one of the flat suction boxes **31**. Instead of this, however, the upper wire **12** can also be conducted up to the wire suction roll **20**. There, as shown, it can wrap around a small part (or, alternatively, a larger part) of the circumference of the wire suction roll and then be returned via the reversing roll **19**.

In the embodiment shown in FIG. **5**, the twin-wire zone, as a whole, extends substantially in horizontal direction. The individual elements are substantially the same as in the embodiment of FIG. **4**. However, there is the difference that the drainage strips **57** and **58** lying in the second section II of the twin-wire zone are arranged along a downwardly curved path of the twin-wire zone. Accordingly, an upwardly curved forming shoe **16, 23** is provided in the first section I and in the third section III of the twin-wire zone. This embodiment is advisable, in particular, for the modernizing of existing Fourdrinier paper machines.

The embodiments shown have the feature in common that, in the second section II of the twin-wire zone, there are present preferably n flexibly supported strips **27/57** and n+**1** rigidly supported strips. However, it is also possible to make the number of flexibly supported strips equal to or greater by one than the number of rigidly supported strips. Instead of a rigidly supported strip, a feed or discharge edge of a drainage box can also be provided. The minimum number n of flexibly supported strips is two (see FIG. **4**). However, three or four flexibly supported strips are preferred.

What is claimed is:

1. A method for the production of a paper web from a fiber suspension in a twin wire former comprising:

causing first and second web forming wire belts to travel along a path together to form a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, each wire belt forming an endless loop;

feeding the wire belts across a single forming roll at the start of the path through the twin wire zone;

supporting the wire belts such as to form a wedge shaped entrance slot into the twin wire zone;

supplying a fiber suspension from a headbox directly to the wedge shaped entrance slot of the twin wire zone;

draining water from the fiber suspension by means of the forming roll in order to start the forming of the web from the fiber suspension;

feeding the wire belts with the fiber suspension and the web being generated therebetween downstream of the forming roll between a plurality of first drainage strips, which are positioned within the loop of the first wire belt for contacting the first wire belt, and a plurality of second drainage strips, which are positioned within the loop of the second wire belt for contacting the second wire belt, the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship;

resiliently supporting the first drainage strips against the first wire belt that the strips contact;

rigidly supporting the second drainage strips against the second wire belt;

feeding the wire belts with the web therebetween downstream of said drainage strips across a stationary drainage element and then across a suction roll in the twin wire zone such that as the wire belts travel over the stationary drainage element and over said suction roll, water is drained through the wire belt in contact with said stationary drainage element and with said suction roll; and

maintaining the twin wire zone apart from said single forming roll and said suction roll free of rolls which would deflect the twin wire zone.

2. The method of claim **1**, further comprising supplying a vacuum in the area of the second drainage strips.

3. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts which travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a single forming roll at the start of the path of the wire belts through the twin wire zone; supports which support the wire belts for forming a wedge shaped entrance slot into the first section;

a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

said single forming roll having an open surface to enable drainage of water from the fiber suspension and being curved along the path of the wire belts through the twin wire zone, the single forming roll being engaged by one of the wire belts and being arranged for curving the path of both wire belts around the single forming roll after the entrance of the suspension into the entrance slot;

the twin wire zone having a second section following the first section along the path of the wire belts through the twin wire zone; in the second section, a plurality of the first drainage strips are positioned within the loop of the first wire belt and are for contacting the first wire belt; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; a first strip support which resiliently supports the first drainage strips against the first wire belt that the first strips contact;

a second strip support which supports the second drainage strips rigidly against the second wire belt;

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; drainage elements in the third section, for being engaged by one of the wire belts as the wire belts travel over the drainage elements, the drainage elements including at least one stationary dewatering element followed by a suction roll and having an open surface to enable water to be drained through the wire belt in contact therewith; and

the twin wire zone apart from said single forming roll and said suction roll being free of rolls which deflect the twin wire zone.

4. The twin-wire former of claim **3**, further comprising a supplier of vacuum in the area of the second drainage strips.

5. A method for the production of a paper web from a fiber suspension in a twin wire former comprising:

causing first and second web forming wire belts to travel along a path together to form a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, each wire belt forming an endless loop;

feeding the wire belts across a stationary curved forming shoe at the start of the path through the twin wire zone;

supporting the wire belts such as to form a wedge shaped entrance slot into the twin wire zone;

supplying a fiber suspension from the head box directly to the wedge shaped entrance slot of the twin wire zone;

draining water from the fiber suspension by means of the forming shoe in order to start the forming of the web from the fiber suspension;

feeding the wire belts with the fiber suspension and the web being generated therebetween downstream of the forming shoe between a plurality of first drainage strips, which are positioned within the loop of the first wire belt for contacting the first wire belt, and a plurality or second drainage strips, which are positioned within the loop of the second wire belt for contacting the second wire belt, the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship;

resiliently supporting the first drainage strips against the first wire belt that the strips contact;

rigidly supporting the second drainage strips against the second wire belt;

feeding the wire belts with the web therebetween downstream of said drainage strips across a stationary drainage element and then across a suction roll in the twin wire zone such that as the wire belts travel over the stationary drainage element and the suction roll, water is drained through the wire belt in contact with said stationary drainage element and the suction roll; and

maintaining the twin wire zone apart from said suction roll free of rolls which would deflect the twin wire zone.

6. The method of claim **5**, further comprising supplying a vacuum in the area of the second drainage strips.

7. A twin-wire former for the production of a paper web from a fiber suspension, the twin wire former comprising:

first and second web forming wire belts which travel along a path together for forming a twin wire zone of the twin wire former, with the web between the wire belts as the wire belts travel along the path through the twin wire zone, neither wire belt defining a single wire predrainage zone;

each wire belt forming an endless loop;

the twin wire zone having a first section which includes a stationary curved forming shoe at the start of the path of the wire belts through the twin wire zone; supports which support the wire belts for forming a wedge shaped entrance slot into the first section;

a fiber suspension supplying headbox having an outlet placed and directed for delivering fiber suspension from the headbox to the wedge shaped entrance slot of the first section of the twin wire zone;

said stationary curved forming shoe having an open surface to enable drainage of water from the fiber suspension and being curved along the path of the wire belts through the twin wire zone, the forming shoe being engaged by one of the wire belts and being arranged for curving the path of both wire belts around the forming shoe after the entrance of the suspension into the entrance slot;

the twin wire zone having a second section following the first section along the path of the wire belts through the twin wire zone; in the second section, a plurality of the first drainage strips are positioned within the loop of the first wire belt and are for contacting the first wire belts; in the second section, a plurality of second drainage strips are positioned within the loop of the second wire belt and are for contacting the second wire belt; the first strips being shifted in position along the path of the wire belts with respect to the second strips so that the first and second strips are offset and in a non-opposing relationship; a first strip support which resiliently supports the first drainage strips against the first wire belt that the first strips contact;

a second strip support which supports the second drainage strips rigidly against the second wire belt;

the twin wire zone having a third section following the second section along the path of the wire belts through the twin wire zone; a stationary drainage element followed by a suction roll in the third section, for being engaged by one of the wire belts as the wire belts travel over the stationary drainage element and said suction roll, the stationary drainage element and said suction

roll having an open surface to enable water to be drained through the wire belt in contact therewith; and

the twin wire zone apart from said suction roll being free of rolls which deflect the twin wire zone.

8. The twin-wire former of claim **7**, further comprising a supplier of vacuum in the area of the second drainage strips.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,972,168
DATED : October 26, 1999
INVENTOR(S) : Egelhof, et. al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Please correct the first name of the 7th inventor's legal representative as follows:
[75] Else Bück, legal representative

Please add the following missing priority data:
[30] **Foreign Application Priority Data**
August 22, 1989 [DE] Germany....P 39 27 597.3

Please correct the Related U.S. Application Data as follows:
[62] Continuation of application No. 09/023,435, Feb. 13, 1998, which is a continuation of application No. 08/556,769, Nov. 2, 1995, Pat. No. 5,718,805, which is a continuation of application No. 08/286,948, Aug. 8, 1994, Pat. No. 5,500,091, which is a continuation of application No. 08/055,918, April 29, 1993, Pat. No. 5,389,206, which is a continuation of application No. 07/773,965, Nov. 12, 1998, abandoned, **filed as application No. PCT/EP90/01313, Aug. 9, 1990.**

Signed and Sealed this

Thirtieth Day of May, 2000

Attest:

Q. TODD DICKINSON

Attesting Officer

Director of Patents and Trademarks

EXHIBIT 3

The Sheet-Forming Process

A Project of the Fluid Mechanics Committee

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Library of Congress Catalog
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Fourth Printing

Foreword

In response to member requests, TAPPI PRESS is reprinting a limited number of this classic publication. Although Chapter 2 (the practical aspects) is out of date, chapter 1 is still technically sound.

Sheet Forming Process is currently being revised by the Fluid Mechanics Committee of the Engineering Division.

TAPPI PRESS
March, 1994

Preface

In his summary and appraisal of the 1965 papermaking symposium in Cambridge, England, Dr. Gallay raised the question of whether a conflict existed between two concepts of sheet forming expressed in separate papers presented at the symposium (*1*). In one paper by Wahren and his associates from Sweden, it was explained that fiber suspensions at papermaking consistencies consisted of physically entangled, three-dimensional networks of fiber. In a second paper by Radvan and his associates from England, it was shown that the paper sheet was constructed of more or less discrete two-dimensional layers. Is it contradictory then that two-dimensional layers of fiber can be produced from a suspension of three-dimensional networks?

Gallay goes on to say that of course these concepts are not in conflict because there is more involved in the sheet-forming process than the simple dewatering of a three-dimensional network. For example, an important effect which contributes to reducing Wahren's networks to Radvan's planar sheets is turbulent shear, which is generated in the free suspension and disperses the fiber networks before they are deposited as a sheet. Thus, as they participate in the sheet-forming process, these concepts are not contradictory, but complementary.

This question of Gallay's and its implications illustrate the dynamic and diversified nature of the forming process. Sheet forming is accomplished by a variety of devices, including handsheet molds, fourdrinier and cylinder-vat machines, suction roll formers, and the newly emerging twin-wire formers. The elementary operation in all of these devices consists simply of the drainage of an aqueous suspension of fibers on a fine-mesh wire screen. When considered in depth, however, the sheet-forming process may involve a myriad of different effects. To mention a few, in addition to turbulence, there is the decay of turbulence and simultaneous reflocculation of the fiber networks, the variable and even reversible rates of drainage, the filtration and retention of fibers on wire grids, the planar shear between the free suspension and the formed mat, the compaction of the formed mat, the transport and retention of fine particles in the mat, and the manifold effects on a fourdrinier of table rolls, a dandy roll, and shake. In all of its variations, sheet forming is a complicated process.

The knowledge of the forming process has accumulated from a variety of viewpoints, generally concerned with singular effects. This knowledge is predominately empirical, but in a few areas, theory has been extensively developed. It is the intent in this monograph to assemble a comprehensible, realistic picture of the forming process, nonrigorous and incomplete though it may be, from this large body of knowledge. The theme of the monograph is sheet structure, and the objective is to define the basic process mechanisms by which the fibers are manipulated to yield the characteristic structure of paper. It is neither an operational manual for the various sheet-forming devices nor a complete and up-to-date compilation of them.

For other reviews of the sheet-forming process, the reader may wish to refer to the references (*1–7, 122*) cited at the end of this monograph.

ACKNOWLEDGMENTS

The author is indebted to Tom McKearn, Beloit Corporation, for his extensive literature searches and accumulation of reference material for this monograph; to Dave Appel, Kimberly-Clark Corporation, and Börje Wahlström, Axel Johnson and Company, for their critical review of the original manuscript and suggestions to improve it; to Audria Allen, Beloit Corporation, for carefully typing the many drafts of this work; and to the various authors and publishers with whose permission the figures from other publications have been reproduced.

Contents

high-quality moderate-weight grades at moderately high speeds, it can be tolerated in the forming of these heavier weight coarse multi-ply grades because they run at much lower speeds and because a much lower quality of formation of single ply is acceptable for these coarse grades. Moreover, when these formation degrading and orienting effects of the roof clearance become too intense, they can be relieved by increasing the clearance at the tip of the roof, allowing a greater discharge of the undrained suspension, which is drained subsequently under a free surface.

In its application to lightweight tissue forming, roll formers compete primarily with fourdriniers, and an obvious advantage is the saving in equipment and space requirement. Just as for multi-ply board applications, the roll former is an efficient drainage device in which pressure as well as vacuum can be applied and a much shorter length of the forming zone is required compared to the relatively inefficient fourdrinier table. For the tissue-forming conditions of large drainage capacity, low basis weight, and low fines content of the furnish, it is possible to use very low consistencies, on the order of 0.1 to 0.2% (*4*), for obtaining a uniform formation.

Probably the greatest advantage of roll formers over the fourdriniers for tissue forming is the absence of a free surface along the forming zone. Thus the sensitivity of the free surface to waves and eruptions at high speeds with the consequent damage to the formed mat and non-uniform concentrations generated by the irregular surface limit the speed of the present fourdrinier machines to about 2800 ft/min. Without the complications of a free surface, tissue roll formers have approached speeds of 5000 ft/min (*126*).

The potentially damaging effects of high shear rates developed in the narrow gap under the forming roof are avoided because of the other prevailing conditions of dispersion and drainage rate in these tissue formers. The large dilution and high turbulence developed in the narrow approach channels preclude any pronounced fiber orientation or network structure, so there is a narrow and well-defined interface between the mobile fibers in free suspension and the formed mat. The mat resists the distortion by the shear since it is thin and is held tightly to the wire by the high drainage rate. However, such high-speed operation is limited to very lightweight sheets and low consistencies since the mat stabilizing force of drainage falls off rapidly with increasing weight of the mat and the suppression of turbulence and network formation increases markedly with increasing consistency.

One of the major problems in high-speed tissue forming is the couching of the sheet from the forming wire. At the high drainage rates used, the fiber becomes tightly embedded in the wire, causing an intense wire mark or incomplete release and picking of the sheet at pickup (*116*). In one recent design, this problem is bypassed by forming the sheet directly on the felt, between the felt and a wire nipped together around the forming roll (*127*). This arrangement has been extensively developed in commercial practice and it was reported recently that machines of this design attained a speed of a mile a minute (*128*). In an even more radical development for tissue grades, the sheet is formed directly on the hot Yankee dryer between the dryer surface and a wire wrapping the dryer (*129*).

It is paradoxical that roll formers are used for the extreme cases of the slower speed multi-ply boards and the higher speed lightweight tissues, but are not suitable for the large majority of intermediate moderate-weight grades made at moderate speeds. It is the high mean shear characteristic of this design which militates against its wider application. A conceivable improvement would be some form of boundary-layer control along the stationary roof to reduce this shear. Obviously an effective method to obtain this control would be to move the roof or the confining boundary at the same speed as the roll and thereby eliminate the boundary layer. This direction of thinking leads logically to the design concept of twin-wire formers, in which the sheet is formed between two moving wires. Let us proceed with a discussion of these types of formers.

TWO-WIRE FORMERS

The idea of forming paper webs between two wire screens was conceived at least as early as 1875 (*130*), but in the last decade or so, there has been a resurgence of interest in the idea and it promises to become a commercially viable method for many paper grades. One of its first commercially successful applications was the forming of multi-ply boards, for which the machine was comprised of four top-wire units mounted in series along a single bottom wire as sketched in Fig. 2.10 (*131*). In this application, it competes with the cylinder-vat machine chiefly and provides improvements in ply bonding, sheet handling, speed, uniformity of formation, and basis-weight profile. A strong ply bond is developed between plies, because a high degree of conformance of the subsequent plies is obtained by forming them directly on top of the preceding ones rather than combining them after they have been formed and partially dewatered as in the cylinder-vat machines and roll

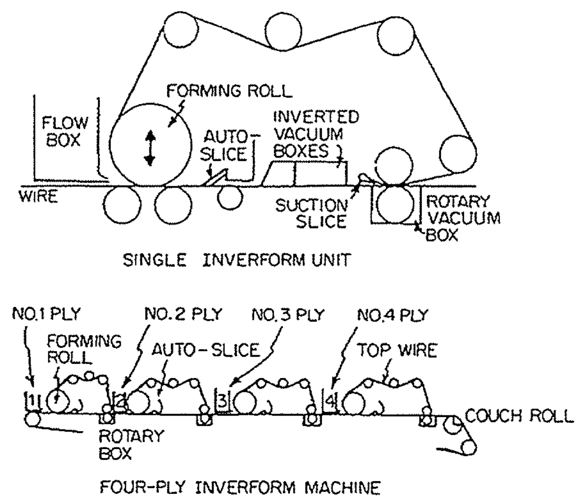

Fig. 2.10. Multi-ply twin-wire machine. (Inverform is a trade name of the St. Anne's Board Mill Co., Ltd.) [After Attwood and Lawrence (*132*).]

formers. It is even claimed that this conformance of one ply to the adjacent one is so complete that formation defects such as air holes in the preceding ply are corrected by the following plies (*131*). The non-uniformities in any individual ply then tend to be leveled out and masked in the overall sheet for an improved formation.

The problem of peeling the sheet from the forming mold and dropoff from the carrying felt in the cylinder-vat machines and roll formers is obviated in this twin-wire former by carrying the sheet on top of the bottom wire. In addition to improving the operating efficiency, this eliminates a speed barrier of the cylinder-vat machine and roll formers. But the greatest contribution to the increased speed capacity of this multi-ply former is the increased drainage rate obtained by developing pressure in the suspension between the wires, where it wraps the rolls and auto-slice, and by the suction applied with inverted vacuum boxes.

In contrast to the large flocs formed and deposited in the mat during the emergence phase in cylinder-vat machines, a more uniform metering of the comparatively well-dispersed stock to the forming zone is obtained with the headbox discharge and forming-roll nip system of this multi-ply twin-wire method. At low speeds in this machine, there is not sufficient velocity in the flow to develop the head necessary to drain the suspension in the nip without a drastic expansion of the flow stream and backflow in the nip. As a consequence, a pond of greater depth

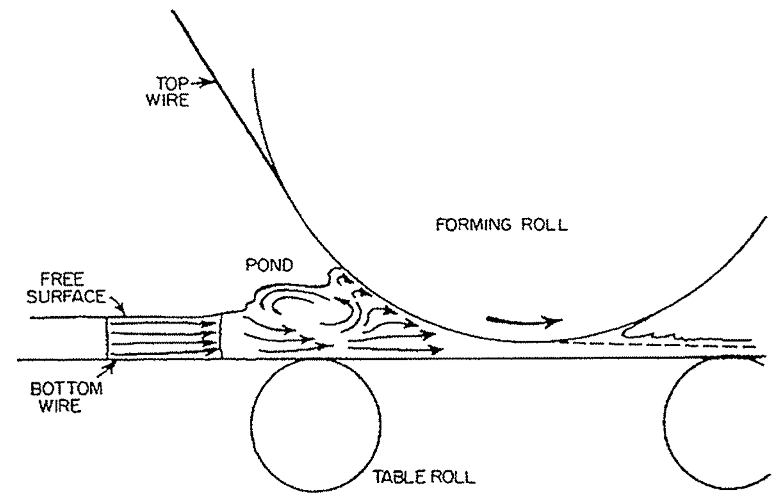

Fig. 2.11. Backflow pond in the forming roll nip.

than the flow stream is sustained at the nip, as indicated in Fig. 2.11, in which moderately intense turbulence is generated by backflow (*132*). An important difference between the behavior of this forming roll pond and the flow in the ridge formed at the ingoing nip of the dandy roll illustrated in Fig. 2.7 is the much greater depth of the free surface pond. The turbulence diffuses through practically the entire thickness of the fiber layer, which is in free suspension at the ingoing nip of the forming roll. The shear generated in the ingoing nip of the dandy roll, whether it becomes turbulent or not, is confined only to the top layers of the mat. A more extensive specification of the conditions leading to this pond development is given by Baines (*133*), where it is explained that the backflow tendency increases both with decreasing speed and increasing flow resistance of the wire screens. The free streamline patterns for jet flows having a velocity U_j into a stationary wire screen nip shown in Fig. 2.12 indicate the effect of increasing screen resistance. These patterns would apply equally well for screens of constant resistance and jets of decreasing velocity. With increasing machine speed however, a much smaller degree of jet expansion is required to generate the pressure and drainage rate necessary to avoid backflow in the nip. Thus the initial drainage rate through the bare screen increases with pressure according to the quadratic relationship involving both viscous and inertial resistances (*134*):

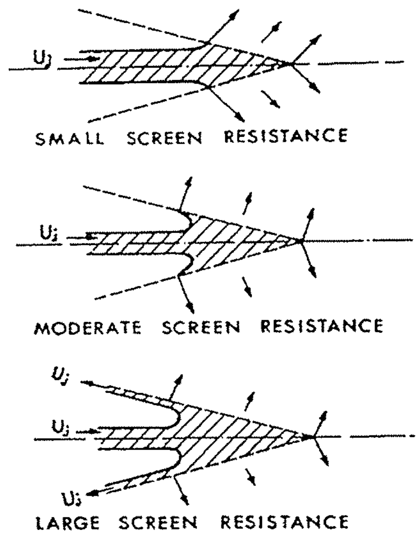

Fig. 2.12. Backflow patterns in twin-wire nips. [After Baines (*133*).]

$$\Delta P = a\mu U + bpU^2 \tag{16}$$

[Note that this equation is identical to Eq. 3 (p. 10) for high-velocity filtration of fiber mats. Wire screens are, of course, just a special case of porous media and the same analytical treatment applies.] On the other hand, the pressure rise due to the expansion of the jet is wholly inertial and varies as the square of the jet velocity. So with increasing machine speed, the drainage flow developed by the impingement force of the jet stream in a wire-screen nip of constant geometry increases at a greater rate than the degree of jet expansion. For this reason, the pond at the nip becomes smaller and the backflow eventually disappears with increasing speed (*48, 132*). An additional beneficial effect of this turbulent pond at low speeds is that it contributes to the fiber dispersion in the immediate forming zone.

The advantages of this multiple twin-wire former are obtained at a high cost, however, for each separate ply requires a complete fourdrinier-type assembly, a comparatively expensive device alone. In view of this, machines of this design have only a limited application for grades where the large equipment costs can be justified by the high production rate possible with it.

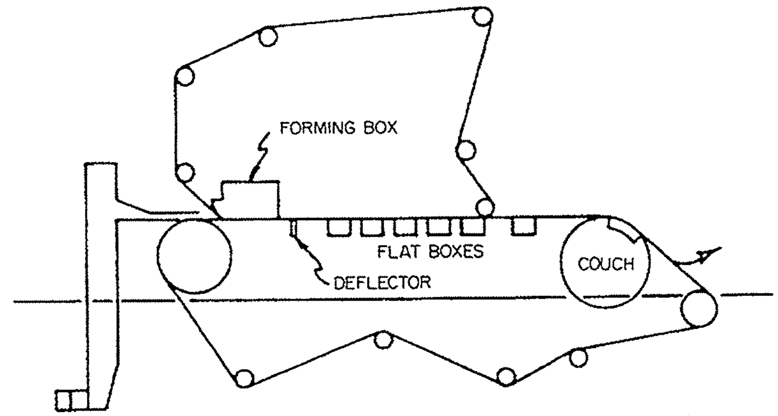

Fig. 2.13. Twinverform machine. (*From the Beloit Corp.*)

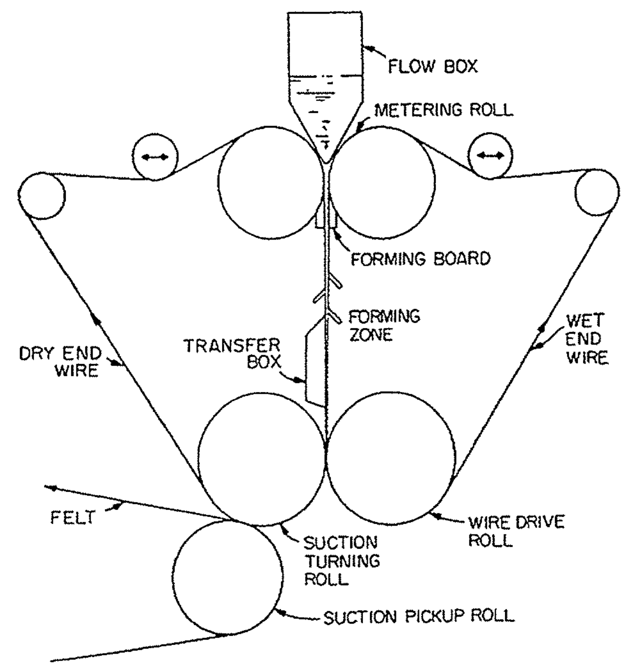

Fig. 2.14. Verti-forma machine. [After Schaffrath and Green (*135*).]

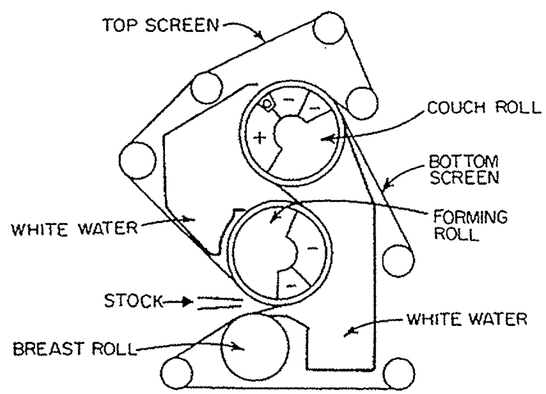

Fig. 2.15. Papriformer machine. [After deMontigny *et al.* (*48*).]

A second area of twin-wire former application which appears to have a great potential is in the forming of single-ply grades of moderate weight (20 to 60 lb/3000 ft^2) normally made on fourdrinier machines at moderate speeds (800 to 2500 ft/min). Schematic diagrams of three different designs of this type of former, the Twinverform, Verti-forma* (*135*), and Papriformer, are shown in Figs. 2.13, 2.14, and 2.15. The first two of these methods are already in commercial operation (*47, 136*).

An inherent feature of this type of former is the more or less symmetrical drainage of the suspension from both sides. Accordingly, the resulting sheet structure, with regard to the "fines" distribution particularly, is substantially symmetrical and non-two-sided (discussed on pp. 24–26 and illustrated in Figs. 1.12 and 1.13). For this reason principally, this method of forming is particularly attractive for publication grades which may have a high filler content and to which coating and/or printing is to be applied to both sides. These grades include magazine coating base sheets, newsprint, and directory paper and these have been the grades of the first commercial installations (*47, 136*). In spite of the fact that both surfaces of the twin-wire-formed sheets are technically wire sides, compared with the wire side of fourdrinier sheets from similar furnishes, both of these surfaces are improved with respect to print quality and wire mark (*47, 48*). Although there is an apparent loss of fines from the surfaces of the twin-wire-formed sheets, it is not nearly so pronounced as in the fourdrinier

*Black Clawson Company trade name.

sheets as indicated in Figs. 1.12 and 1.13. The improved wire mark is attributed to a less intense drainage pulse and fluidization of the mat that occurs in the early drainage on the fourdrinier, even though the total drainage is much more rapid with the twin-wire formers.

In addition to the drainage symmetry, another basically beneficial effect of the twin-wire system is the absence of a free surface in the forming zone. Just as with the roll formers, the elimination of the free surface allows higher levels of turbulence to be used in the immediate forming zone and this precludes the free surface eruptions as a speed barrier. In the Twinverform and Papriformer devices, this feature is exploited by using headboxes which produce relatively highly turbulent discharges for better initial dispersion. Thus a turbulent discharge is a natural complement to the twin-wire former with its ability to rapidly drain the suspension before it fully reflocculates. According to Whitney's definition of papermaking on page 59 then, two-wire formers should be regarded as healthy competitors in the field of commercial forming machines. In these two formers employing high turbulent discharges, the headbox plays a more direct role in the forming process than it does on the fourdrinier, where microdiffusion along the table tends to obscure the headbox characteristics. For this reason there is also less tolerance of large-scale variations in concentration, flow velocity, and secondary flow patterns of the discharge, for these too will be reflected in the sheet structure. Furthermore, with these highly turbulent jets, it is important to closely couple the headbox slice to the nip between the wires to avoid disintegration and entrainment of air in the turbulent free jet, which may cause defects in the sheet formation (*17*). It is of particular importance to avoid back-flow or rejection at the nip since this will create flow patterns which are reflected in the sheet formation. As discussed above, this is easy to avoid because at the high velocities of these applications, only a slight expansion of the jet is necessary to develop adequate drainage pressures in the nip. In contrast to the other two formers discussed above, the Verti-forma (Fig. 2.14) apparently has a relatively low level of turbulence in the headbox discharge, which is very stable, and depends to a major extent on the development of shear in the stock between the wires along the forming zone to achieve an improved formation. This shear is generated by bending the wires slightly over the deflector blades pressed against the wires on alternate sides of the wire sandwich, and the angle and degree of projection of these blades into the wires have been cited as settings of critical importance to the operation of this former (*137*).

A primary source of drainage force in all of these two-wire formers is the pressure developed between the wires by drawing the wire sandwich around a curved suction box, roll, or deflector blades. Sufficient pressure p must be developed between the wires taking a curved path of radius r to support the outside wire under its tension T; i.e., $p = T/r$. The wire tension therefore is a means for controlling the rate of drainage, particularly in the Papriformer where the degree of wire wrap around the roll is so large. An increase in pressure in the flow between the wires must occur at the expense of velocity by the Bernoulli relationship (*133*). However, the drag exerted on the decelerated stock by the wires tends to mitigate this velocity reduction, and as the dewatered mats thicken, this drag becomes predominant and the entire fiber structure between the wires is maintained at wire speed. So long as the suspension is being filtered, though, this velocity change may give rise to shear gradients which tend to orient the fiber in the machine direction as they are deposited in the mat, and this orientation may occur in the inner as well as the outer layers of the mat. A distribution of fiber orientation through the thickness of the sheet may be obtained then with the inner layers less, equally, or more oriented than the outer layers depending largely on the initial velocity of the discharge jet. These conditions are indicated in Fig. 2.16 for sheets made on the Papriformer (*48*). An advantageous effect of the high turbulence developed in the headbox discharge is to reduce this fiber-orienting tendency.

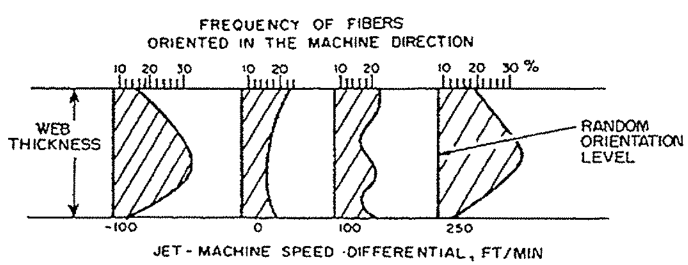

Fig. 2.16. Distributions of fiber orientation through the thickness of Papriformer sheets. [After deMontigny *et al.* (*48*).]

Compared to the fourdrinier, these twin-wire formers are a relatively simple forming system, involving readily defined profiles of drainage pressures, and the effects of mat compaction and fines retention in them might be simulated in laboratory systems. Thus an analysis of the Papriformer indicates that the forming length varies directly with

the basis weight, speed, and filtration resistance of the mat and inversely with the outside wire tension (*133*). Corresponding analyses of the fourdrinier process, on the other hand, are much more difficult because of the complex profiles of drainage over table rolls; also, the effects of dynamic mat compaction and fines retention have never been adequately characterized by laboratory experiments (*7*). It is anticipated that the theoretical analysis of twin-wire forming will be highly developed eventually because of its basic simplicity. For the same reason, these systems are amenable to computer control and the automation of them should be easier than that of the fourdrinier process.

CYLINDER-VAT MACHINES

Cylinder-vat machines come in two basic varieties: a uniflow type, in which the stock is introduced into the vat at the ingoing face of the cylinder mold, and a counterflow type, in which the stock is introduced into the vat at the emerging face of the cylinder mold. Schematic diagrams of these devices are shown in Fig. 2.17. Although these machines are highly versatile and have been used to produce as wide a range of grades as the fourdrinier, their predominant application today is in the production of heavyweight multi-ply boards in which one machine may include as many as ten of these forming units in series. They are still competitive for the production of multi-ply boards basically because they are relatively inexpensive forming devices with the ability to make heavyweight sheets in multiple plies using different furnishes for the different plies. It is an important economic advantage to be able to construct boards, for use as consumer packaging primarily, with the outer plies comprised of high-quality bleached chemical pulp for appearance and printability and to use cheaper waste paper and groundwood furnishes for the inner plies to give bulk and stiffness to the board.

An outstanding limitation of these cylinder machines is that they can only be operated at low speeds. At high speeds, water begins to rim the inside of the cylinder mold and centrifugal force tends to force the water through the mold and lift the mat from its surface. For the 36-in. diameter mold, the limiting speed due to this effect has been indicated to be about 415 ft/min (*138*). At this speed, the centrifugal acceleration on the periphery of the 36-in. diameter mold equals that of gravity, but the significance of this is somewhat uncertain. In addition to their speed limitations, these machines produce comparatively poor sheet qualities; specifically, highly flocculated formation, large varia-